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Objectives of the study (summarized in Chapter I) were (1) to propose a task-oriented viewpoint in which the scientist actively participates as an integral part of the system in performing research tasks, (2) to identify major system planning decisions and criterion concepts for use in evaluation of proposed information systems, and (3) to construct a planning guide. Chapter II deals with functional requirements of a system. The task-oriented philosophy is described using a grant-supported research project as the task to be accomplished by the system. Chapter III is concerned with the technical description of a system. A system planning model was constructed. Chapter IV defines and classifies administrative functions and identifies management tasks. Chapter V describes the system planning and development process. This chapter identifies activities occurring and level of system description realizable during each of five planning and development phases. Appendix A gives a research project model. Appendix B includes a summary of functional, technical and administrative aspects of the observed information systems and a discussion of major characteristics associated with different information system models. (CC)

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# GUIDELINES FOR PLANNING A TASK-ORIENTED INFORMATION SYSTEM

John A. Whittenburg
Anne W. Schumacher

W/V-RR-69/2-Wd

Submitted to:

National Science Foundation
Special Projects Program
Office of Science Information Service
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UNIVERSITY OF MINNESOTA

Submitted by:

Whittenburg, Vaughan Associates, Inc.
4810 Beauregard Street
Alexandria, Virginia 22312

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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# CHAPTER I

# INTRODUCTION

# I. Introduction

## A. Objective and Scope

One of the missions of the National Science Foundation (NSF) is to support the effective dissemination of scientific information (102). The Office of Science Information Service (OSIS) within NSF has been assigned a major responsibility for carrying out this mission. One part of this responsibility involves the awarding of information system development grants to universities and professional societies. The traditional role of OSIS with respect to these system development grants has been supportive and administrative in character. That is, financial support is provided to universities and professional societies through the administrative mechanisms of a grant. Within fairly broad policy guidelines and limited constraints provided by NSF, the grantee assumes primary responsibility for planning, executing, and documenting the grant-supported project. This traditional relationship between NSF and the universities/societies has proved to be a fairly harmonious and satisfactory one. However, an accelerating trend has been evolving most noticeably during the past two years which is necessitating an examination of this traditional relationship. This trend is briefly described below and discussed in greater detail in Section B of this chapter.

The trend involves the broadening requirement of all government funded agencies and organizations to spell out in some detail the expected benefits, costs, research and development (R&D) time frame, and risks associated with system development projects submitted for fiscal support. There are at least two obvious factors contributing to this trend: (1) an increasing number of agencies and programs are competing for the federal dollar and (2) a growing realization that the planning and development of complex systems, for example, computer-based information systems, is quite expensive, usually requires a number of years for the systems to be made operational, and generally entails a significant degree of uncertainty or risk regarding the eventual effectiveness of the developed system.

Not only are there increasing numbers of organizations and programs requesting federal funding but also the systems being funded are becoming more complex and expensive in time, talent, and money to plan and develop. Given this situation, the decision problem of effectively allocating a finite amount of federal funds requires, during the entire system planning and development cycle, information and data on the projected benefits, costs, and risks as inputs to the decision process. The end product or objective of this decision process is to allocate funds to those information system alternatives which show the greatest likelihood of providing significant benefits within established cost constraints. The degree and breadth of prior planning needed to provide these types of inputs to the decision process has not been a normal procedure required in the past of those seeking federal grants.

It is one thing to formulate a requirement within the domain of computer-based information systems. It is quite a different matter to effectively implement it. The accumulation to date of system planning and development experience has rather consistently revealed the existence of a gap between required decision inputs (relevant to projected costs, benefits, and risks) and actual performance in generating either comprehensive or, in some cases, meaningful decision inputs.

Excluding the evident difficulty of forecasting the future as one must when planning new systems, there are at least two perhaps not so obvious factors contributing to the system planning and development problem.

First, the evaluation of alternative information system concepts or operational systems is made difficult by considering the system user as a recipient of the services of the system. This position forces the system planner to view the user as the ultimate criterion source regarding the utility of the system. Given this orientation, the major alternative choices available to an investigator are either (1) verbal responses of the user concerning the acceptability of the service and the relevance of the retrieved information or (2) externally observable/measurable behavior of the user which might be grouped under the general rubric "system usage". Both of the available choices have led, methodologically speaking, thorny existences. Recently published studies are described later in this chapter to highlight methodological difficulties encountered with this orientation. Furthermore, to effectively implement either choice, it is necessary for the system in question to be either operationally simulated or on-line in an operational status. However, the immediate problem facing the system planner is to obtain useful inputs when the system is in the earliest planning stages. During the very early planning stages, neither of the above choices are feasible; consequently, the system planner must either (1) design the system on the basis of verbal expressions of information needs supplied by members of the potential user population or (2) shift to a different orientation such as designing the system based on the characteristics of the information being published within a particular discipline or problem area. In this latter instance, the system planner has shifted from a user-need orientation to an information-supply orientation.

Second, the sheer complexity associated with planning and developing computer-based systems produces its own problems. These include the large number of system alternatives that are available, particularly at the component and subsystem levels; the potentially significant and multiple performance and cost measures from which to select and weigh with respect to relative importance; the many perspectives that must be considered, that is, system planner, developer, administrator, funder, and user; and the large number of temporal and environmentally produced uncertainties and constraints. Obviously, these problems pose a most difficult system planning requirement.

It is this gap between the required and the realized system planning cost/benefit information and data for management decision making which provided the impetus for this project. Within this problem context, the project was undertaken with a threefold objective in mind: (1) to propose a task-oriented viewpoint in which the scientist actively participates as an integral part of the system in performing research tasks as an alternative to the system-support viewpoint in which the scientist is considered as a user of the products or services provided by a system, (2) to identify major system planning decisions and criterion concepts for guiding an objective and comprehensive evaluation of proposed information systems, and (3) to construct a planning guide using the outputs of (1) and (2) above which identifies major system planning and development activities, inputs, and decisions appropriate at different phases in the system planning and development cycle.

The scope of this project is briefly summarized in the following statements.

. The information systems of concern are restricted to complex computer-based systems designed to perform or contribute to the performance of a number of different functions; for example, computational, research management, bibliographic, clerical, simulation. These complex information systems, even under ideal conditions, require a three to five year planning and development cycle. Finally, the hardware and software technology considered within the scope of this planning guide is well within the state-of-the-art with most of the components being "off-the-shelf" variety.

. The "user", or more accurately, the participant population are scientists working in academic environments who hold positions at the assistant/associate professor level and who also have had two or three years research experience in a specific content area. Furthermore, the scientists are generally independent investigators with limited time to conduct research and limited research facilities at their disposal. Finally, their research work is supported by grants for the most part, and their research findings are generally reported at professional meetings and published in professional journals.

. The scientist requirements of the computer-based information system are those involving the accomplishment of grant-supported research projects. The research project activities of interest range from the initial preparation of a proposal to the final submission of an approved article for publication. All tasks involved in the planning, conduct, and documentation of a grant-supported research project are to be considered as potential candidates for accomplishment by the integrated scientist/computer-based system.

. The computer-based system of concern to this planning guide is one which is either located on the university campus or accessible through remote input/output devices. In either case, the system-provided services are administratively supported by the university.

## B. Discussion of the Problem

In Section A, an observation was made concerning the broadening requirement for government funded agencies and organizations to project expected benefits, risks, and costs in their proposed R&D programs. Increasing competition for the federal dollar and steadily growing costs of conducting R&D projects were identified as two of the factors contributing to this trend. In line with this observation, an article by Frederick Seitz in the September 1966 American Scientist Journal (84) discussed the need for an increasing rate of federal support of fundamental research to meet the rapidly rising costs. He also pointed out that the increasing needs of our society for money represents one of the reasons why the support of basic research operates, for the most part, on a fixed percentage of the national income rather than on the level of research productivity that can be attained. At a quite recent meeting sponsored by the New York Academy of Sciences entitled "The Crisis Facing American Science", Linus Pauling (19) contended that the reported 15% annual increase in federal support produced less than 7.5% increase in scientific activity because (1) research is being carried out on harder problems involving more complex and expensive equipment and facilities, (2) inflation reduces the purchasing power of each research dollar, and (3) wages and costs of services which support research programs have generally increased.

At the same meeting, Walter S. Baer, from the Office of Science and Technology, also made a number of points relevant to this trend. First, federal grants for basic research are spent in many different ways--for graduate and post-doctoral assistantships, for faculty summer salaries, for equipment, for research materials, and for general overhead expenses. Some of these items are more critical and timely than others. Given the fact that federal support of R&D programs is levelling off, it is important that members of the scientific community help establish priorities to assist the decision makers in allocating federal funds. Second, the number of claimants for federal funds is quite large. To quote Mr. Baer, . . . "should the Vietnam war end tomorrow, there would be more than enough claimants to spend that money five times over." Third, the decision process of allocating federal funds to support various proposed R&D programs is usually one in which all of the alternatives appear attractive and potentially beneficial. Therefore, it is important that the particular relevance of each program and the ways in which anticipated benefits might be achieved be described in detail.

It was also noted in Section A that this growing requirement to define expected benefits and projected costs of proposed computer-based information systems is encountering significant difficulties. A number of factors appear to contribute to this difficulty. Some of these factors derive from the sheer complexity of the system planning and development task, and others stem from the system support philosophy commonly followed by system planners. Major contributing factors are described next.

An orientation which prevails in the design of computer-based information systems is the viewpoint that the information system supports the user. In other words, the user is not considered an integral part of the information system but rather a recipient of the products or services of the system. This common orientation very likely stems from the traditional relationship of an individual information user to a library. However, this historical relationship has posed a number of knotty methodological problems associated with the selection, development, and evaluation of an information system; problems which have been receiving increasing attention during the past few years. Probably the single greatest problem stemming from the traditional relationship of the user to the information system concerns the evaluation of a system. Some illustrative examples from quite recently published studies should highlight this problem.

A 1967 report by Wessel and Cohrssen (98) , involving a comprehensive literature search and state-of-the-art on criteria for evaluating the effectiveness of library operations and services, concludes that existing criteria and standards were found to be unsatisfactory. This was because only some aspects of libraries lend themselves to quantitative measurement, such as number of items cataloged, ordered or found in a period of time, whereas the quantitative measurement of the value of a library service or product such as a literature search, bibliography, or current awareness service seemed more difficult to assess.

In the 1966 Proceedings of the Second Congress on Information System Science (78), Ruth Davis noted that the persistence of the evaluation problem over a period of 15 years is related to a large number of difficulties. Some of these difficulties include lack of well-defined objectives, lack of meaningful models, uncertainty concerning measures of effectiveness, and lack of quantitative criteria. An article in 1966 by Parker and Paisley in the American Psychologist (73) pointed out that a major problem area requiring research is the development of criterion measures for the design and evaluation of information systems. Donald W. King in the 1968 Annual Review of Information Science and Technology (22), concluded that "the literature of 1967, like that of earlier years, is weak with respect to cost data . . . . The general problem of benefits is even farther from solution than that of costs." Finally, Marvel Hall in a 1965 article entitled, "Summary of Study Conference on Evaluation of Document Searching Systems and Procedures" (39), remarked that attendees at the conference generally agreed that one of the major problems pertained to the lack of adequate performance measures and criteria.

It is proposed that the basic root of this difficulty lies with the pivotal concept of "relevance." The general recognition of the centrality of this criterion concept to the system support orientation has led to a number of studies and papers within the past few years. A 1965 study by Human Sciences Research, Inc. (87) on the methodology for test and evaluation of document retrieval systems emphasized that a better understanding of the concept of relevance is needed. A recently completed two-year effort by System Development Corporation (23) involving 15 individual studies on relevance judgments suggests that relevance judgments can be and are influenced by a number of factors. These include the skills and attitudes of the particular judges used, the documents and document sets used, the particular information requirement statements, the instructions and setting in which the concepts and definitions of relevance are employed in the judgments, and the type of rating scale or other medium used to express the judgments. The authors of the report contend that serious doubt exists with respect to studies using relevance scores as stable criteria for system or subsystem evaluation in instances where the sources of variation cited above have not been recognized and properly controlled.

In a more pointed vein, in a paper in 1963, Doyle (27) questioned the use of relevance as an adequate criterion of system retrieval effectiveness. He discussed the possible discrepancy between an individual's measurable outward expression of an information need and his real information need. A year later, Cuadra (24) argued for the retention of relevance as a useful construct while, at the same time, he recognized that additional effort is needed to develop meaningful relevance measures. However, in a 1968 article entitled "Some Questions Concerning Information Need", O'Connor (69) noted in the beginning of his paper that the questions raised by Cuadra in this 1964 article have not been answered. O'Connor continued by identifying three possible meanings of the statement "satisfy the user's information need" and, for each possible meaning, he raised a number of questions which must be answered before the meaning of the concept can be considered sufficiently clear to those who advocate its use as a system performance criterion.

In summary, the current procedure of employing the system user as the primary source for system evaluation has raised a number of criterion-related problems, and it is unlikely that these problems will be quickly resolved. A change in the conceptualization of the role of the user to the system may prove to be a more satisfactory approach. This approach is discussed in the next chapter of this report.

A second characteristic of present day specialized information systems is the large number of alternative system concepts, configurations, and components. This stems primarily from the rapid advances being made in information system technology. The impact of this technology is shown in terms of the rapidly growing number and diversity of hardware and software alternatives for performing various information system functions and subfunctions. The system planner and the system buyer are faced with a large number of discrete hardware/software components. In addition, the many ways that these components can be combined to form system configurations which, in turn, can be used to form a variety of systems, create a most complex cost/effectiveness decision problem. These components, subsystems, and system alternatives vary widely on many dimensions. These include number and types of services provided; acquisition, operating, and maintenance costs involved; availability of the systems to various numbers and types of users; types of information that can be processed and stored, such as inventory data, test results, patents, maps, engineering drawings; output media such as teletype, TV display, microforms, and printed page; and mode of use, that is, current awareness and retrospective search and retrieval of information.

A third characteristic associated with specialized information systems is the diversity of perspectives. The system designer/developer, the system operator/maintainer, the system buyer, and the system user represent four different ways of viewing an information system. Each of these perspectives possesses different sets of requirements, constraints, and criteria by which alternative possibilities are generated, considered, evaluated, accepted, and utilized. These different perspectives do not necessarily belong to different individuals or to different organizations. The same individual or organization may be required to view the same system from more than one perspective. It is the perspective that is the key concept not individuals and organizations.

The system designer/developer desires to achieve, understandably, a wide market for his hardware/software components. To reach a large number of potential users, he is interested in providing a wide range of services at competitive prices. The system operator/maintainer, on the other hand, is more concerned with minimum operating and maintenance requirements, a high degree of system reliability, compatibility with existing facilities and services, and adequate day-to-day as well as long termlogistic support for the system. The system buyer, from another point of view, is looking for a system which possesses a high degree of growth potential, a wide range of services to meet a variety of institutional or organizational needs, and an acceptable level of both acquisition and operating costs. Finally, the system user is concerned with obtaining a high level of system performance, immediate availability of the system when required, and capability of the system for meeting his information needs as they vary with respect to specificity and type. Compromises and trade-offs, of necessity, are required among these different perspectives.

A fourth characteristic of specialized information systems pertains to the increasing trend toward evolutionary development. This trend is, in large measure, a function of the rapid growth in information related technology. The relatively rapid advances being made in the state-of-the-art have produced two major effects which enhance this growing trend toward system evolution. First, the advancing technology produces a situation in which the next decade appears to hold great promise with respect to tremendous improvements in current capabilities and in new revolutionary concepts. Because of the complexity and degree of sophistication, it generally requires ten to fifteen years to bring these theoretically possible concepts into operational reality. The temptation is naturally strong to put "one's money" on these future hopes, but, the full maturation of these theoretically feasible concepts requires talent, money, and time.

As Melcher (61) points out in an article entitled "Automation: Rosy Prospects and Cold Facts," there are a number of unfulfilled expectations in the area of automation. Since the system is not-in-being, so to speak, there are little or no empirical cost/benefit data available with which to assess the concept objectively, other than what might be labelled as "assumption-based" analyses. And the more innovative the concept, the less chance there is to find current systems which are similar enough in character to use as gross models for estimating the cost/benefit characteristics of the future system. The prevailing solution to such a situation is to "learn-and-obtain-data-as-the-system-evolves," that is, to support research and exploratory development efforts as well as prototype development and production efforts.

In accordance with this approach, a common strategy is to perform these research and development activities within an operational or user context to enhance the "validity" of the findings. A major question of interest to system buyers is at what stage in the evolution of a system concept can a comprehensive and objective basis be used to estimate the probable costs/benefits of the system if and when it becomes operational. The earlier in this cycle one can make the decision to continue to support or to reject a candidate, the less the cost.

To further complicate the issue, the other end of the spectrum is anchored by systems, subsystems, and components which are in-being and have accumulated an empirical base of cost/effectiveness data, although, perhaps in a different environment. The dilemma is whether to "buy" an immediately available off-the-shelf system in which cost and performance are fairly predictable, but which promises less capabilities, or to cast one's lot with the lesser known but more promising future system. With almost unlimited resources, both major options might be pursued simultaneously. However, the growing need for some solution to the information problem, coupled with limited funds, limited talent, and limited time make it necessary for some systematic procedure to be developed and used to guide the selection of a system from among available alternatives.

A fifth factor related to this evolutionary characteristic of information systems pertains to the integration of new components, subsystems, and systems into an on-going information system. Consider military systems as one extreme. The proposed new system may be constrained only by the nature of the inputs such as documents and reports and possibly some of the output requirements such as user locations and transportation means. Now consider university-based systems as the other extreme. A proposed system might be constrained at all levels; that is, system, subsystem, and component, and throughout all of the information system functions; including acquisition, cataloging, abstracting, indexing, extracting, storage, dissemination, and end use. In addition, these new systems are introduced into some existing environment. This environment involves constraints of various types including, for example, building, storage area, availability of water and electricity, and heating and air conditioning. These multiple constraints often lead the system planner and designer in the direction of either automating existing and highly constrained manual procedures rather than tailoring the procedures to meet the new capabilities offered by the computer technology, or selecting a system concept which is far lesser in scope and capabilities than originally desired.

The material presented thus far can be summarized succinctly in the following five statements.

. There are limited federal funds available to support R&D programs which are growing in numbers and in costs.

. The primary aim of responsible decision makers is to allocate federal funds to those R&D programs which show the greatest likelihood of providing significant benefits within established cost constraints.

. Objective and comprehensive data on projected benefits, costs, and risks are needed as inputs to support the allocation process.

. Experience to date involving the planning, development, and operation of computer-based information systems has revealed considerable difficulty in providing to the decision makers these needed information and data inputs in a timely, accurate, and complete manner.

. The sheer number of factors and uncertainties involved in planning and developing computer-based information systems, coupled with the presently prevailing system support philosophy, are judged to be the two primary sources of the difficulty experienced.

A system planning guide, to be potentially useful, must be responsive to these two inferred sources of difficulty. As a consequence, the approach selected in the conduct of this project reflects this orientation.

## C. Approach and Organization of Report

The approach adopted in developing the planning guide reveals four general characteristics.

First, the level of description achieved in the information system planning guide may be characterized as being macroanalytic in contrast to microanalytic. There are a number of reasons why the broader macroanalytic approach represented the only feasible alternative: (1) the number and complexity of the factors involved in information system planning would completely prohibit an adequate microanalytic treatment given the time, skills, and support available. (2) The attempt to substitute a task-oriented philosophy for the content-oriented and system-support orientation requires an initial structuring and developmental effort. A macroanalytic approach is appropriate during this initial formulation and definitional phase. (3) This report is primarily management-focussed and not technically-focussed. References to selected books and documents which describe in detail relevant system analytic tools and operational research techniques are noted in appropriate places throughout this report.

Second, an attempt has been made to utilize a few unifying constructs as a means of integrating and simplifying the task of organizing, screening, evaluating, and selecting system alternatives. A graphic construct of the system planning decision process was developed to facilitate the integration of major decision components and the interactive process associated with the resolution of major system planning decisions.

Third, the approach taken may be described as being largely prescriptive rather than descriptive in nature. The term prescriptive, in this context, refers to the use of general guidelines organized into an overall system planning structure rather than a step-by-step cookbook concept of prescriptiveness. The goal, in this report, is to achieve a level of detail which, on the one hand, is sufficiently broad in scope to enable the required creative abilities of the system manager to effectively function within a specific system context, and yet on the other hand, is sufficiently structured so as to provide the system manager with a set of systematic and ordered guidelines to facilitate the overall planning and developmental process.

Fourth, the approach includes both static and dynamic views of the system planning and development process. The static view includes information on the functional, technical, and administrative factors associated with system planning. The dynamic view integrates these three parts of a system description into a phase by phase analysis of the planning and development process. At each phase, the level of system description achievable is identified, the types of decisions required are described, and the kinds of inputs possible for evaluating system alternatives are noted.

The remainder of this report is organized into four chapters. Chapter II deals with the functional requirements of a system. In this chapter, the task-oriented philosophy is described using a grant-supported research project as the task to be accomplished by the combined scientist/computer-based system. The numerous elements which make up a functional description are briefly covered in this chapter while the supporting and more detailed considerations of these elements are provided in Appendix A to this report. Chapter III is concerned with the technical description of a system. A system planning model was constructed to facilitate the systematic consideration of the multiple and varied planning decisions, criteria, and constraints found with complex information systems. Chapter IV defines and classifies basic administrative functions and identifies management tasks which need to be accomplished in establishing a system planning and development organization. Chapter V provides a dynamic description of the system planning and development process. This last chapter identifies the kinds of functional, technical, and administrative activities occurring, and level of system description realizable during each of five system planning and development phases. Three types of supporting information are provided in Appendix B. They are the names of individuals interviewed during site visits to universities in which system planning, development, and operational activities are being pursued; a summary of the functional, technical, and administrative aspects of the observed information systems, and a discussion of major characteristics associated with different information system models.

# CHAPTER II

# FUNCTIONAL DESCRIPTION

# II. Functional Description

## A. Introduction

The last quarter century has seen a dramatic increase in the amount of scientific and technological information.[1] Since 1961 a number of attempts have been made to estimate the volume and exponential growth of scientific and technological information ( 2 ,36 , 45 ,52 ,72). In a recent article Licklider (51) stated, "The body of recorded scientific and technological information now has a volume of about ten trillion alphanumeric characters (i.e., letters, numerals, and punctuation marks) and is increasing along (what for lack of precise data is usually assumed to be) an exponential curve characterized by a doubling time in the range 10-15 years . . . " Linus Pauling (19) estimated the growth in science for the period 1933-1965 by taking the number of million words per year published in the Physical Review and since 1958 the Physical Review Letters. Measured this way over the 32-year period scientific research has had an average increase of 7.5% per year. A slightly more conservative growth rate was obtained by May (57). The results of May's analysis, based on mathematics literature, indicate that the well known hypothesis of exponential growth of scientific literature is confirmed, but at a rate less than 1/2 of that generally found by other investigators; that is, about 2.5% per year, doubling about four times a century rather than every ten to fifteen years.

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[1] In this context, the term information is used to represent the recorded alphanumeric characteristics (that is, letters, numerals, and punctuation marks) while knowledge pertains to the output achieved in terms of descriptive or predictive utility by systematically arranging, organizing, or relating available information items according to various conceptual schemes.

These various estimates all point up the significant growth rate of scientific and technological information. To describe this phenomenon, such phrases as "information explosion" and "flood-of-information" are commonly found in technical and professional articles. However, some of the contexts in which these expressions are used seem to imply that the dramatic growth in scientific and technological information that we are experiencing is somehow the problem to be solved. Suggestions have been made to raise journal standards in order to reduce the rate of publication, or to hold a moratorium on the publishing of current research findings until the publication lag is caught up. These suggestions imply that slowing down the rate at which scientific and technological findings are reported would help reduce the information problem. This viewpoint is inconsistent with the continuing efforts of a substantial segment of our society to significantly increase (1) the number of trained scientists and engineers in this country and (2) the amount of fiscal support to productively carry out basic and applied research activities. And, it is certainly incompatible with the prevailing, although questionable, "publish or perish" philosophy.

One of the goals of a scientifically and technologically oriented society is to optimize the ratio of knowledge generated to information generated. Assuming that, under ideal conditions, the ratio is a constant, then by increasing the flow or production of scientific information, the fund or corpus of knowledge is proportionately increased. The proper concern then would seem to be to direct attention to those conditions or events which tend to degrade or reduce this "idealized" ratio. Viewed in this manner, the problem is the perceived existence of an inadequate growth rate of knowledge compared to the growth rate of information. Or, to state it another way, it is necessary to direct attention to the point in time when research is being planned and conducted as well as the point in time when findings are being reported and disseminated. This perspective emphasizes the role of scientists as producers of information as well as users of information.

The events or conditions which could adversely affect the idealized knowledge/information growth ratio may be quite numerous and many of them are perhaps unsuspected. However, if it is acceptable to reason backwards from the nature of the corrective actions currently being taken as a way of inferring the causal factors, there are commonly held to be at least two primary types of concerns associated with the growth of scientific knowledge. The first concern is the increasing probability that a scientist or engineer will miss relevant work done by others and, as a consequence, not be in an optimum position to most effectively build onto existing knowledge in a particular area. The second concern is the increasing probability that there will be an adverse trade-off in time spent by the scientist or engineer in productive and creative thinking versus time spent in searching, retrieving, extracting, or organizing relevant findings. These conditions could adversely affect the knowledge growth rate as compared to the information growth rate.

The five major kinds of solutions currently being planned, developed, or utilized may be grouped under one or the other types of concern expressed in the preceding paragraph. Two of the solutions are built around broad and heterogenous information bases, that is, library directed solutions, and the remaining three solutions are designed around relatively narrow and homogenous information bases, that is, specialized information centers.

The first type of solution is directed at increasing the size of the document base through use of networks which connect a number of libraries or document sources to user sources. The effect of this approach is to make available to users a much larger store of documents than is economically feasible within the context of a single library. The network solution is oriented, among other goals, to solving the problem of users not being aware of relevant information in their field. Examples of regional library network systems are the RICE System at Rice University, the BEACON or Academic Library Network System at the University of Colorado, and the New England Regional Library Network.

A second type of solution is focussed on the problem of reducing total system response time through automation. As the number of volumes increases through networking or acquisition in document/library systems, there is normally an associated increase in the time required to perform the basic document processing functions. One major goal of the automation approach is to reduce the amount of time the user must spend in searching, locating, and retrieving relevant documents. A number of universities are currently planning and developing computer-based library systems in which one or more of the document processing functions are being automated. Some typical examples include University of Chicago, Stanford University, Columbia University, Pennsylvania State University, and the University of California at Berkeley.

A third solution involves the collection, reproduction, and wide dissemination of scientific and technological titles, abstracts, bibliographies, and reports. The larger federally sponsored information systems tend to fall into this group. Examples include the Clearinghouse for Federal Scientific and Technical Information, the Defense Documentation Center (DDC) for Department of Defense contracts, The National Referral Center for Science and Technology (NRCST) supported by NSF, NASA's Scientific and Technical Information Facility at Documentation, Inc., and the Atomic Energy Commission's Division of Technical Information Extension (DTIE) (68,92). The massive reproduction and wide dissemination of scientific and technological literature are directed at reducing the possibility that relevant research might be missed by geographically and organizationally separated groups of scientists and engineers.

A fourth solution involves the smaller information systems or centers which are specialized or personalized and focus on restricted inputs and selected dissemination of information to interested scientists and engineers. Representative examples include the National Library of Medicine MEDLARS Information Systems Division (30) which produces Index Medicus, other recurring bibliographies, and demand searches; Mitre Corporation (47) which selectively distributes contractual reports to 20 user groups; and the SDI System at Ames, Iowa (102) which serve about 200 cases involving the University of Iowa and 30 diverse industrial firms. The objective of these systems is to maximize the amount of relevant information disseminated to users and thus to minimize the amount of total time that might be spent in searching, retrieving, and reviewing materials if the user were forced to perform the entire task of screening relevant from irrelevant information.

A fifth solution involves a mixture of systems which, however, have one major characteristic in common, they provide the individual user with special information services. These special services involve some type of operation on the information contained in documents. These special services include extracting "chunks" of information, preparing special bibliographies, performing reviews, and writing summaries. Some of the systems possess a specialized information base, while others contain a broad subject matter and discipline base. Some are designed around computer components; othere are largely manual in make up. Although these systems vary widely in their structural, functional, and operational characteristics, at least one of their common goals is to actively assist the individual user by performing a range of operations on the document-stored information. The desired outcome of these special services is to permit the scientist and the engineer to allocate a greater percentage of his time to those tasks which require more creative and analytical skills and knowledge. Examples include the MACTIP System at MIT (48) which is currently undergoing conversion to operational status; Project Intrex at MIT (72) which is in the planning stage; the CIS Retrieval System at Lehigh University (102) which is conducting on-line computer experiments on the "intellectual processing" associated with information search and retrieval activities; the Brain Information System (BIS) at UCLA (30); and the Pennsylvania Technical Assistance Program (PENNTAP) at Pennsylvania State University.

Some of the special services provided by these systems are similar to what the proposed task-oriented information system would provide. For example, the MACTIP System was used by Professor Sanborn Brown and a group of his co-workers at MIT to compile a book on basic plasma data (12 ). In this instance, the system actively participated with the scientists in preparing the book. This example illustrates the capability of an on-line computer-based system to function jointly with the scientist in producing an output.

The task-oriented information system approach, like the special services solution, is primarily focussed on the second type of concern just discussed; that is, the efficient allocation of the scientist's time to those research tasks requiring the creative and analytical capabilities of man. However, unlike the special service type of solution, the task approach is (1) research output focussed rather than service to user oriented and, most importantly, (2) planned and developed specifically around the requirements and characteristics of phases, tasks, and subtasks associated with the grant-supported research projects in contrast to being general purpose in nature. The "special purpose" orientation requires the system planner to identify and describe, where feasible, the activities associated with accomplishment of the task. This planning requirement is discussed in the remaining sections of this chapter.

## B. Task-Oriented Approach

It is proposed that seven major classes of information are needed as inputs for specifying functional requirements. The set of functional requirements are needed to guide the planning and design of the task-oriented computer-based information system. These task-related classes of information include:

- a general background description of the university-based research project,
- a detailed analysis of the phases, tasks, and subtasks generic to grant supported research projects,
- an identification of the major variations in research project characteristics as a function of differences in subject matter, research objectives, and methodology used,
- a grouping of the various research project phases, tasks, and subtasks into a few discrete categories characterized by a high degree of commonality in terms of their performance or functional requirements,
- the development of appropriate product (benefit) criteria and identification of relevant criterion sources for evaluating research project outputs,
- a determination of existing attitudes and behavioral characteristics of the selected scientist population regarding the research project performance requirements, and
- an identification of environmentally originating contributions and constraints which are relevant as inputs to system planning.

It is beyond the scope of this study to accomplish the required complete, and detailed functional analysis of grant-supported research projects. Rather, the preliminary development of a research structure is presented with sufficient accompanying description to facilitate an effective level of communication which conveys the essence of this task-oriented approach. Extensive use is made of graphic illustrations as a means of identifying the kinds of data and information needed to accomplish a complete functional specification.

## C. General Description

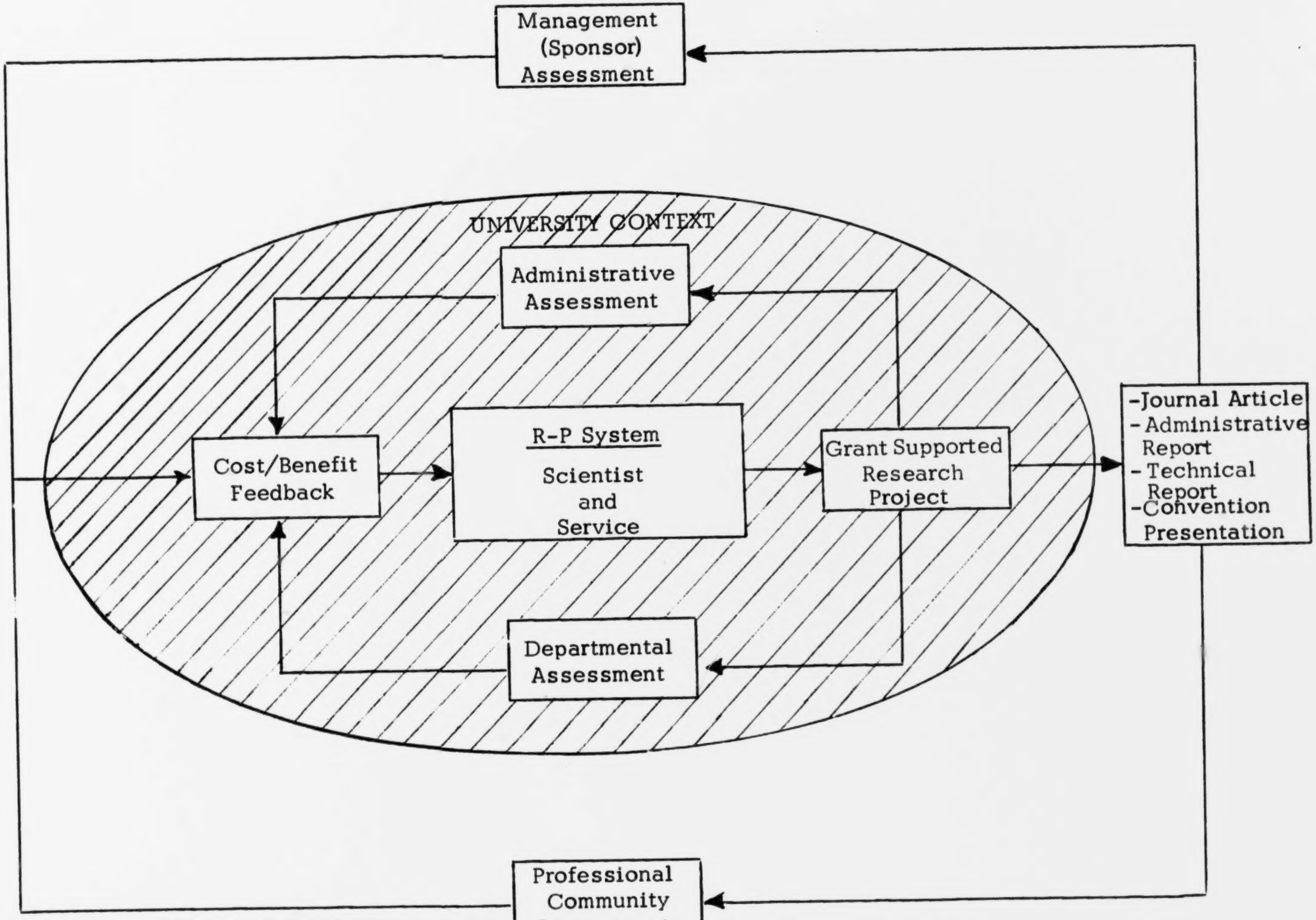
Figure 1 shows a schematic representation of the Research Project (R-P) System located within the university environment. The major points illustrated in the figure are given below, and their significance with respect to the task-oriented approach is discussed immediately following.

. The planning, conduct, and documentation of a grant supported research project represents the mission or purpose of the R-P System. The grant supported research project has an externally definable beginning (a proposal) and end (a final report). Like a number of other goal directed and sequentially dependent activities, a research project can be meaningfully broken down into phases, tasks, and subtasks. Each of these parts can be identified and described with varying degrees of confidence and detail in terms of input, process, and output characteristics. It is useful to view the subtask, task, and phase outputs as sub-goals of the system. The final or overall output/goal is ideally a completely and accurately documented research report which is of timely scientific value.

. The components of the R-P System, like other systems, consist of people, hardware, and software. The R-P System which performs the various research project activities is composed of two major subsystems; i.e., a scientist subsystem and a service subsystem, which perform each of the research project subtasks separately or jointly. Even when the two subsystems are processing subtasks independently, however, they must coordinate the inputs and outputs of the various sequentially related subtasks.

. The two major subsystems may be considered as independent subsystems. That is, they perform activities other than those directly related to the accomplishment of a research project. Here we are

Figure 1. A Schematic Representation of the Research Project (R-P) System (including its context and external cost/benefit sources)


Management
(Sponsor)
Assessment
UNIVERSITY CONTEXT
Administrative Assessment
Cost/Benefit Feedback
R-P System
Scientist and Service
Grant Supported Research Project
-Journal Article
-Administrative Report
-Technical Report
-Convention Presentation
Departmental Assessment
Professional Community

concerned only with those activities which directly contribute to the accomplishment of the research project.

. The grant supported research projects of interest to this study are performed within the university environment. The university environment may be viewed as consisting of several organizational structures designed to fulfill the numerous and diverse functions of a university. These major functional entities are educational, administrative, research, athletic, counseling, and social in nature. The two university based functions of primary interest here are basic research and what might generally be labelled as project administration. Project administration includes those individuals or time, facilities, and procedures within the university organization which are directly concerned with the administrative and logistical support activities associated with the procurement, administrative monitoring, and contractual completion of externally funded basic research projects. The basic research function is performed by the scientific and professional segment of the university which proposes, plans, conducts, supervises, and evaluates basic research. These scientists generally have available for their support some technical facilities, student assistance and scientific literature, and professional colleagues who serve as sounding-boards for their ideas and research-related findings.

. Beyond the immediate university context there exists two important entities, the scientific community as a whole and the agencies or organizations which support, through grants, basic research in the university environment. In a sense, there are three relevant contexts concerned with grant supported research projects. The most immediate context is the R-P System itself, and, specifically, the scientist subsystem and the service subsystem. A broader context consists of the university environment and particularly the project administration and professional or departmental colleagues. The broadest context includes the sponsoring agencies and those members of the overall scientific community whose discipline and problem area interests overlap those of the particular university based scientist in question. These three contexts and the six major entities within the three contexts represent the major sources of requirements, constraints, and criteria for generating and evaluating alternative R-P System concepts.

. The proposed concept of a R-P System shifts the traditional relationship of the user to the system. Rather than considering the scientist as the recipient or user of the services or products of an information system, the scientist and the service jointly contribute as producers to the research project outputs. The accomplished phases, tasks, subtasks constitute the system's outputs. Also, the so-called user of the research project system has grown to include interested university members and the professional community as a whole. By shifting the relationship of the scientist to the system and by expanding the meaning of the term user, some of the major traditional evaluation problems have been by-passed. The research project outputs of the system can be evaluated independently by departmental colleagues, professional journal editors, and the professional community, as a whole, as well as by the individual scientist. Scientific methodology, professional journal requirements, and cognizant scientists in the problem area of concern provide a rish source of standards that can be applied to the research product outputs.

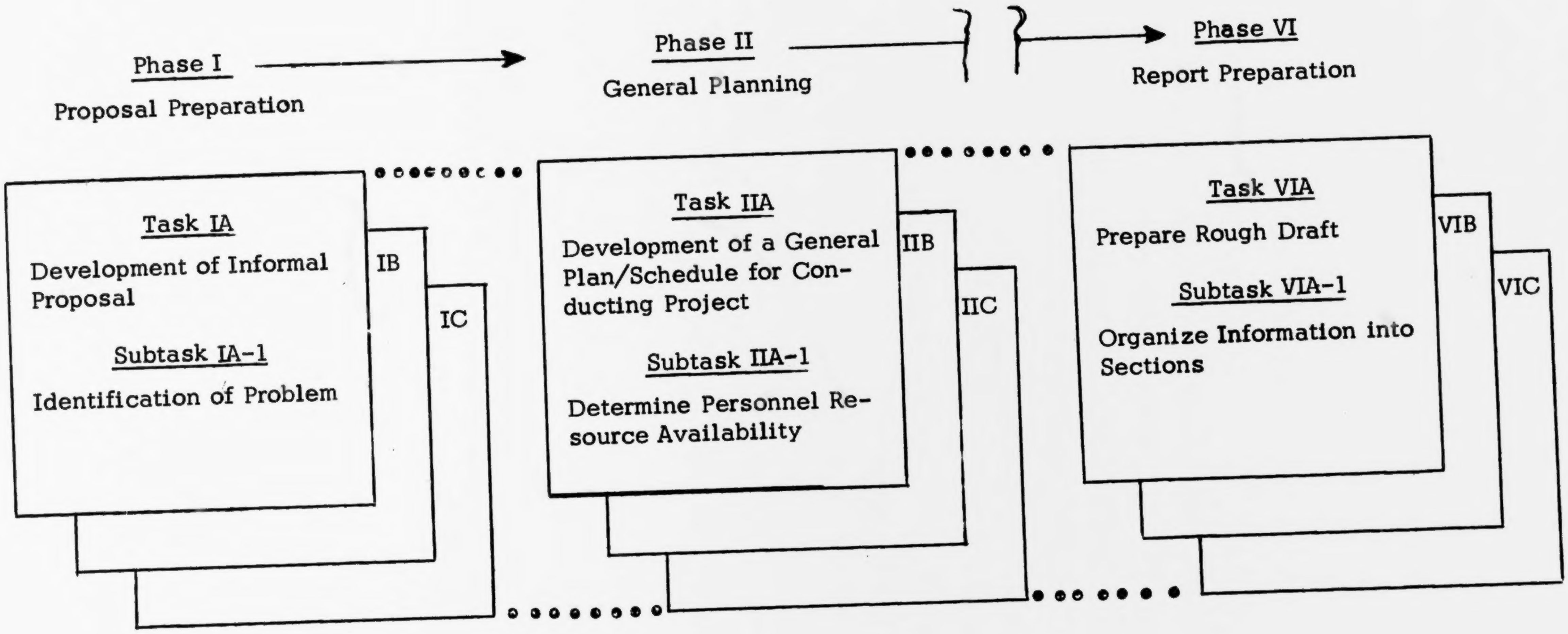
. The use of the research project model as the foundation for the R-P System serves to combine a functional or task-oriented scheme with the more traditional content-oriented information system scheme. System generated inquiries are concerned with fulfilling not only specific information needs but also information needs for some specific purpose or task. One may visualize, for example, a three-dimensional matrix consisting of a functional dimension which lays out the phases, tasks, and subtasks of a research project, a content dimension which organizes material with respect to its subject matter, and a procedural dimension which consists of computer programs or specified manual procedures for processing particular content-bearing units of information needed to accomplish some specific subtask. For example, a computer program may be developed for editing grant proposals. The basic program may permit variations to allow for differences in subject matter or in potential sponsoring agency requirements. The potential ability to specify subtask outputs, subject matter inputs, and processing requirements represents a shift from the more restricted emphasis on subject matter inputs.

. Use of the research project model as the basis for the R-P System extends the scope of an information system to include all of those activities associated with the accomplishment of a research project. The R-P System will not only perform the information retrieval function but will also perform such functions as computation, simulation, editing, abstracting, and controlling of stimulus presentation and recording of responses of subjects during experimental trials. It will encompass the full range of capabilities, services, and products currently being explored, used, or developed in existing computer-based systems.

## D. Research Project Phases, Tasks, and Subtasks

Figure 2 shows an incomplete schematic representation of the research project phases, tasks, and subtasks. The grant supported research project is made up of six phases: a proposal preparation phase, a general planning phase, a detailed planning phase, a data collection phase, an analysis and interpretation phase, and a report preparation phase. Within each phase, there are tasks normally associated with the accomplishment of the particular phase. And, for each task, there are subtasks to be performed. A preliminary

Figure 2. An Incomplete Schematic Representation of Research Project Phases, Tasks, and Subtasks


Phase I
Proposal Preparation
Phase II
General Planning
Phase VI
Report Preparation
Task IA
Development of Informal Proposal
Subtask IA-1
Identification of Problem
IB
IC
Task IIA
Development of a General Plan/Schedule for Conducting Project
Subtask IIA-1
Determine Personnel Resource Availability
IIB
IIC
Task VIA
Prepare Rough Draft
Subtask VIA-1
Organize Information into Sections
VIB
VIC

version of such a research project model is presented in Appendix A of this report. The model is intended to be a comprehensive and generic representation of the phases, tasks, and subtasks associated with the conduct of grant supported research projects. The model is designed to encompass the full range of activities that might be performed during grant supported research projects, although the performance of any given research project may not require the execution of all tasks and subtasks listed.

## E. R-P System Performance Requirements

A necessary task to be performed during the early planning stages of any system is the specification of the nature and level of performance that will be required to achieve the objectives of some specified job or mission. The tasks and subtasks of the research project model represent sub-objectives or sub-goals to be accomplished during each of the project phases. Accomplishment of each sub-objective or sub-goal requires a certain level and type of performance. System components are selected or designed to cost/effectively perform these tasks and subtasks in order to achieve the stated sub-objectives.

In this report, an initial step has been taken towards the statement of research project performance requirements. A general classification scheme has been developed. This preliminary scheme reflects an initial judgment concerning the types of skills and knowledge required to perform each of the research project tasks and subtasks. It proposes that three broad groups of skills and knowledge are brought into play during the conduct of a successful grant-supported research project. The three classes of skills and knowledge are scientific, managerial, and informational in nature.

Scientific skills and knowledge refer to technical and creative capabilities. Technical skills and knowledge pertain to both subject matter content and methodological abilities acquired by the scientist during his formal education and during the subsequent period of time when he is a teacher and researcher in professional/scientific environments. Creative skills are much more difficult to define, however, there are four typesof events in which the term creative thinking is commonly applied. First, the early perception or diagnosis of a problem is one type of event. The ability to perceive a deficiency in an existing theory and the recognition of a deficiency in a current technique or method are examples. A second type of event is the realization of the importance or significance of a finding or occurrence, although the discovery may have been of an accidental nature. A third is the ability to develop a more encompassing theory than an existing one which will account for more of the phenomena in a particular problem area. The development of a more effective technique or method falls into this category. A fourth type of event is the ability to perceive that knowledge or a technique developed in one area can be applied to another type of problem often in an entirely different area.

Managerial skills include resource management and clerical skills. Resource management refers to the cluster of skills and knowledge related to the planning, allocation, coordination, and supervision of both human and material resources. Activities such as scheduling, allocating personnel to various research tasks, matching projected research effort to money requirements, and effective utilization of facilities and space represent examples of resource management. Clerical skills include such activities as typing, editing, transmitting materials, coding, filing, and organizing materials.

Informational capabilities fall into an area which overlaps both the scientific category and the managerial category. Some of the specific activities associated with information handling, such as acquisition, compilation, and organization of chunks of information, emphasize requirements for both clerical and resource management skills. Other specific activities associated with information processing require technical and perhaps even creative skills and knowledge. Nevertheless, from a system planning and development point of view it is useful to separate this category from both the managerial and the scientific categories. The informational category provides a transition between the traditional concept of specialized information services for scientists and the proposed concept of a research project model. Furthermore, the informational category is restricted to those research activities involving information obtained about the ideas, work, and findings of other scientists. For example, a number of the tasks and subtasks clearly emphasize the retrieval and organization of externally originated information, that is, review, screening, and extraction/tagging of relevant chunks of information found in the literature and the review of literature for discussions of relevant variables and their characteristics. The hypothesized type and level of performance capabilities required throughout the planning, conduct, and documentation of a research project are illustrated in Figure 3. This figure presents an obviously oversimplified picture. Extensive, analytical, and empirical efforts are required to factor the tasks and subtasks during each phase into differentially weighted skill and knowledge requirements.

## F. Research Project Paradigms

Another requirement in system planning is to achieve an operational description of the selected task. The description should be both comprehensive and yet sufficiently detailed to serve as an effective input to system-based decision making. In other words, the description

Figure 3

## Level of Skill and Knowledge Requirements for Specific Phases of a Research Project

| Skills and Knowledge Requirements / Phases | Scientific | Informational | Managerial |
|---|---|---|---|
| Phase I<br>Proposal Preparation | High | High | Low |
| Phase II<br>General Planning | Low | Medium | High |
| Phase III<br>Detailed Planning | Medium | Medium | Medium |
| Phase IV<br>Data Collection | Medium | Low | Medium |
| Phase V<br>Analysis & Interpretation | High | High | Low |
| Phase VI<br>Report Preparation | Low | Low | High |

should not produce such a voluminous amount of descriptive material that either intellectual comprehensiveness or meaningful manipulation of the data is prevented.

One strategy for helping achieve this balance between depth and breadth of coverage is the grouping of large numbers of task-related activities into relatively few categories. It was stated above that one of the objectives is to develop a list of research project phases, tasks, and subtasks common to most grant-supported research projects. A preliminary effort to develop such a generic list revealed that some tasks and subtasks are common to most, if not all, grant-supported research projects; particularly during Phase I Proposal Preparation and Phase VI Report Preparation. This was found to be less true during Phase II General Planning and Phase V Data Analysis and Interpretation, and even less true during Phase III Detailed Planning and Phase IV Data Collection.

Variations found among grant-supported research projects may stem from a number of factors. Factors which may significantly influence types of research project tasks and subtasks undertaken include differences in research objectives - uncovering the existence of a particular phenomenon versus determining functional relationships among two known phenomena; discipline or subject matter - physical matter versus biological organisms; methodology - experiment versus controlled observation; scale of measurement - ordinal versus ratio; and form of explanation - functional or teleological versus deductive. Given this range of potentially significant factors, the ideal objective is to select or develop a classification scheme which achieves a comprehensive coverage of diverse types of research projects while requiring only a small number of operationally meaningful categories to do the job. A number of possible schemes have been explored in a very preliminary manner.

One classification scheme involves the paradigm model. T. S. Kuhn (50) in his book entitled, The Structure of Scientific Revolutions introduced the term paradigm as a label for grouping together laws, theories, applications, and instrumentation associated with some particular scientific achievement. These paradigms or schools-of-thought tie together a community of practitioners who are provided with a model, problems, and solutions. These are the traditions which the historian describes under such rubrics as "Ptolemaic astronomy (or Copernician), "Aristotelian dynamics" (or Newtonian), "Corpuscular optics" (or wave optics), etc. The significant point is that a paradigm represents a closely integrated way of thinking about and doing scientific research. However, Kuhn points out that the existence of paradigms is restricted to the more mature natural sciences. The social sciences and most of the biological sciences are currently in the pre-paradigm phase of evolution. While the paradigm model does not encompass the full range of disciplines to which this study is addressed, it may prove quite useful as a model for specialized systems which support a well defined community of practitioners in the natural sciences, such as high energy physicists.

Another alternative classification scheme is based on the nature of the subject matter; that is, physical, biological, and social subject matter. In support of this alternative, F. J. Ayala (3 ) in a recent article argued for the scientific autonomy of biology based on the unique functional characteristics of living organisms. These unique functional characteristics, according to Ayala, are not reducible to physics as fostered by some philosophers of science. Teleological explanations are an integral part of biology and living organisms in contrast to physics and physical matter. In a similar vein, J. Jaynes ( 43 ) contrasted the basic nature of physics and psychology. Jaynes postulated that there are many routes to science rather than a unity of science. He states, "My point is that the history, philosophy, and sociology of one science should not be modeled on that of another, that there is no such thing as normal scientific progress, no one pattern of scientific activity, no one criterion of excellence though there may be of aesthetic satisfaction, that there is no one "scientific" method, and no one way of scientific history." Recognizing that the subject matter of the biological and social sciences as well as the physical sciences would have a significant influence on the planning and execution of a research project, one problem in developing a useful classification scheme is to determine where to establish the boundaries. In the same article, Jaynes reviewed a recently published book by Herrnstein and Boring, entitled Source Book in the History of Psychology. Herrnstein and Boring pointed out in their book that there were fifteen separate tracks usually going in different directions, ranging from Fechner's psychophysics to Kohler's gestalt psychology. In addition to the problem of establishing boundaries between different tracks, pursuing this alternative across the full spectrum of disciplines would very likely lead to such a large number of categories as to be unmanageable. By way of contrast, Siever (86) in an article entitled, Science: Observational, Experimental, Historical argues that there is only one kind of science, although there are many styles. He feels that little use will be attained by emphasizing stylistic differences among the various disciplines and methods of research.

A third possible classification scheme hypothesizes that there is a natural clustering of subject matter content, research objectives, and methods. That is, investigators will select a method which best fits the content and objective. As a preliminary check on this hypothesis, a sample of approximately 60 articles published in various journals covering physics, chemistry, biology, and the behavioral sciences were reviewed, and the objectives, methods, and content were extracted and summarized. Although there was some evidence of patterning or clustering, the findings were not sufficiently unambiguous to provide a clear-cut guide for developing a classification scheme based on the clustering hypothesis. Details of this preliminary effort are presented in Appendix A of this report. Although this exploratory effort did not uncover the hypothesized clustering phenomena in a sufficiently definitive form, one useful finding did emerge. The particular methodology used by the scientists dictated, to a large extent, the particular tasks and subtasks involved in the research. While not completely adequate as the basis for a classification scheme, it was decided to tentatively pursue the methodological scheme. The articles reviewed showed that the methodology used by the investigators could be generally grouped into one of four classes: experimental, statistical, observational, and modeling. Figure 4 graphically shows the degree of commonality hypothesized to exist among the four methods during the six phases of a grant-supported project.

In a controlled experiment, the researcher manipulates, within specified limits, certain features in a situation which are assumed to constitute the relevant conditions for the occurrence of the phenomena under study. Manipulation and reproducibility "at-will" are the two major characteristics of the experimental method. The statistical method is characterized by the manipulation of numerically assigned descriptors of various events or objects. Searching for trends or functional relationships is a common objective found with the statistical method. Historical facts, sociometric information, and meteorological data are frequently subjected to the application of the statistical method. Controlled observation represents a deliberate search for contrasting occasions in which the phenomenon is either uniformly manifested or manifested in some cases but not in others. Astronomy serves as a classic example of a science which relies primarily on controlled observation. Also, social sciences and some specialties within the biological sciences frequently use the controlled observation method. Modeling, in this context, refers to the construction of either a functional (mathematical) or structural (physical) model to depict the "true" nature of some phenomena of interest. Modeling is predominately found with the mature

### Figure 4

### Degree of Commonality Among Research Project Paradigms In Terms of Task and Subtask Descriptions

| Paradigms<br>Phases | Experimental | Statistical | Observational | Modelling |
|---|---|---|---|---|
| Phase I<br>Proposal Preparation | ▩ | ▩ | ▩ | ▩ |
| Phase II<br>General Planning | ▨ | ▨ | ▨ | ▨ |
| Phase III<br>Detailed Planning | ░ | ░ | ░ | ░ |
| Phase IV<br>Data Collection | ░ | ░ | ░ | ░ |
| Phase V<br>Analysis and Interpretation | ▨ | ▨ | ▨ | ▨ |
| Phase VI<br>Report Preparation | ▩ | ▩ | ▩ | ▩ |

▩ High Commonality

▨ Some Commonality

░ Low Commonality

physical and chemical sciences. Success in modeling depends on the existence of a wealth of related findings and facts on which to build the model. A recent example of a most successful structural model is the construction of the double helix to depict the make-up of the DNA molecule (97 ).

## G. Objective and Criteria

The preliminary formulation of an overall objective of a grant-supported research project was guided by four considerations. First, the objective should reflect the essential purpose of basic research within the domain of science. Second, the stated objective should be capable of being analyzed into operationally measurable concepts. Third, the stated objective should be consistent with the perspectives and/or goals of those who would have a legitimate and potential interest in the products of grant-supported research. This would specifically include the six entities mentioned earlier: the scientist and service subsystems, the university based project administration and departmental colleagues, and the outside scientific community and agencies which sponsor basic research. Fourth, the stated objective should be sensitive to the scientific information explosion.

A preliminary definition of the objective of a grant-supported research is as follows: "the overall objective of a grant-supported research project is to add to our existing store, scientific knowledge of wide application or generality, in a problem area of active interest to a segment of the scientific community. The three key phrases in this definition are to add to, of wide application or generality, and of active interest." The next three paragraphs briefly discuss these key phrases.

Scientific knowledge may be characterized as an edifice; that is, a large, highly interrelated abstract structure. Symbolically speaking, to add to the existing edifice, it is necessary to be aware, at some selected point in this abstract structure, of the existing knowledge and of the relationships among the related elements of knowledge. The exponential increase in recorded scientific information discussed earlier has led many individuals to question human intellectual ability and interest to adequately understand that which is already known in a particular problem area such that the individual scientist can do productive research at the frontiers of a particular problem area (104). The assumption underlying this position is that failure to be cognizant of all relevant information concerning the problem area decreases the likelihood that the scientist will add to existing knowledge.

The second key phrase of the definition is of wide application or generality. This part of the definition is concerned with the value or significance of the grant-supported research project. More specifically, it is concerned with the inherent importance of the findings generated during the conduct of a research project. At least four types of research findings would have wide application or generality. One type of significant research finding might be labelled as the historical first. Included under this category would be the full range of discoveries involving natural phenomena. A second important finding is the replacement type. Theories which replace other less encompassing or less exacting theories and techniques of observation or measurement which replace less precise or reliable techniques are in this category. Statistical as well as experimental techniques and methods would be included here. The third type is that which possesses social significance. Medical and nuclear research both contribute, albeit in different ways, a large percentage of findings which have social significance. Findings from medical research on cancer, heart disease, and aging possess obvious social significance. Likewise, advances made in controlling nuclear sources of energy would have both economic as well as social importance. The fourth type of significant research finding is that which is transferable. That is, an item of knowledge, a method, or a technique developed in one discipline may be transferred and effectively applied in another discipline or in a quite different problem area within the same discipline. The increasing trend towards interdisciplinary research has accentuated this type of activity.

Finally, science is dynamic in nature and areas of general interest are continually shifting. One factor significant to grant-supported research is the timeliness of the research, that is, the extent to which the proposed research deals with a problem of interest to at least a segment of the professional community and to one or more of the grant-supporting agencies. A general assumption is that the greater the extent that the proposed research treats problem areas of current interest, the greater the likelihood that the research will be funded and the findings awaited with interest. Timeliness pertains not only to the proposal preparation, the planning, and the conduct of the project, but also to the documentation and dissemination of the findings.

Using the preliminary definition of the objective of a grant-supported research project as the point of departure, the next step is to derive criterion concepts. For example, the term "relevance" discussed earlier in this paper is a criterion concept. It embodies the notion or idea that retrieved documents or extracted items of information will meet with varying degrees of success, the information needs of a user. Likewise the task-oriented approach requires the selection of appropriate criterion concepts which reflect the objective of a selected task. In this instance, the planning, conduct, and documentation of a grant-supported research project is the task to be accomplished; and, the preliminary definition stated above is the objective of the task. Criterion concepts are used to evaluate the completed research projects and, by inference, the R-P System, that is, the scientist and service subsystems which produced the research. Once suitable criterion concepts are identified, the next step is to select valid, reliable, and administratively feasible ways of operationally defining the criterion concepts. For convenience, these operational definitions are labelled as criterion measures. Strictly speaking, however, a full definition of a criterion measure would include the event or property of an object to be measured, how the measurement is to be performed, and under what set of conditions. Figure 5 lists three criterion concepts and some alternative ways of operationally defining these criterion concepts in terms of criterion measures.

The criterion concept of adequacy refers to the capability of an R-P System to generate a research project which adds new knowledge. It is assumed that the extent to which the system produces a research report or article which meets the technical, administrative, and professional requirements of scientists and journals is a measure of its ability to add new knowledge. The editors and referees associated with the various professional journals serve as the criterion source for assessing adequacy. Adequate coverage of relevant literature, a logical formulation of the hypothesis, the quality and completeness of the detailed planning, and numerous other factors are examined when a completed research study is being considered for possible publication. Over the past few years considerable debate has been directed at the level of standards exercised by the editors and referees of professional journals. Many individuals feel that their standards should be raised. In essence, this means increasing the value(s)

Figure 5. Criterion Concepts and Alternative Measures of the Research Project

| R-P Objectives | Criterion Concepts | Alternative Criterion Measures |
|---|---|---|
| to add to our existing store, scientific knowledge | Adequacy | - Time from submission to publication approval<br>- Number of draft revisions required<br>- Rejection/acceptance for publication |
| of wide application or generality | Survivability | - Number of different journals in which study is cited<br>- Citation rate over time<br>- Requests for special presentations of work |
| in a problem area of active interest to a segment of the scientific community | Pervasiveness | - Number of pre-prints requested<br>- Shift in publication priority<br>- Number of requests for paper presented at a convention |

assigned to the acceptance-for-publication criteria so that approval for publication is given to only high quality research. Although the question of journal standards is certainly relevant, the criterion concept of adequacy is one of degree rather than a go/no go concept. In other words, as the standards are raised, those studies accepted for publication should be more adequate. As the degree of adequacy increases, then the probability of adding new knowledge to that already existing increases accordingly.

Survivability is a term selected to indicate the adjudged value or worth of the findings obtained on a grant-supported research project. Some possible criterion measures include the number of different journals in which the article is published, the number of different authors who cite the research, whether the author receives professional awards, and the number of different requests by scientific and lay organizations and groups for special presentations by the author.

The concept of pervasiveness was selected to reflect the degree of scientific interest associated with project content. As noted earlier, certain problem areas are of high interest within the scientific community or a segment of it. The extent to which the research project system is concerned with these high interest areas should be measurable in terms of such criteria as total number of requests for pre-prints, an upward shifting in the priority of publication date, and number of requests for a paper given at a convention. Extending the concept of pervasiveness somewhat, it is reasonable to assume that if the nature of the problem being investigated possesses social significance as well as scientific interest, it is likely to receive even greater attention, not only from the scientists but also from the public in general.

The three criterion concepts require the system to be operational or adequately simulated in order to obtain the necessary criterion-related information. Survivability represents the long term criterion concept. A substantial amount of time is required to collect data bearing on this criterion. Pervasiveness may be considered a mid-range criterion. To estimate the degree of pervasiveness, the research product must be widely disseminated to users, and sufficient response time must be permitted. Adequacy is the short-term criterion concept. Journal editors, sponsors, and departmental colleagues should provide a relatively quick indication of the adequacy of the research product.

Within the context of the research project cycle, different criterion sources can be related to the different phases of the research project. Figure 6 summarizes primary criterion perspectives or sources for the various phases of a research project as well as for the completed product.

## H. Scientist Attitudinal and Behavioral Characteristics

Thus far, attention has been directed to the need for identifying and describing activities and performance capabilities required during the planning, conduct, and documentation of a grant-supported research project. The problem of developing a generic list of tasks and subtasks has been discussed. Types of capabilities needed to effectively produce a complete research product have been identified, and a preliminary definition of the objective of a grant-supported research project and three criterion concepts for use in evaluating the quality and timeliness of generated research reports and papers have been introduced. Now the focus of attention shifts from the research project itself to the scientist who is responsible for performing the research and to the context or environment of the research project. To be consistent with the orientation

## Figure 6

## Primary Criterion Perspective/Source During the Research Project Cycle

| Research Project Phases | Primary Criterion Perspective/Source |
|---|---|
| I. Proposal Preparation (and Final Product) | Sponsor and Professional Community |
| II. General Planning | University Administration and Department |
| III. Detailed Planning<br>IV. Data Collection<br>V. Analysis and Interpretation | Scientist and Colleagues/Staff |
| VI. Report Preparation (for Publication and/or Presentation) | Journal Editors/Referees and/or Convention Staff |

adopted in this report, both the scientist and the supporting services should be treated together since the so-called R-P System is composed of both. However, because of the prime importance of the scientist in the R-P System and because historically the scientist and the supporting services are separate, the latter will be treated with environmental considerations.

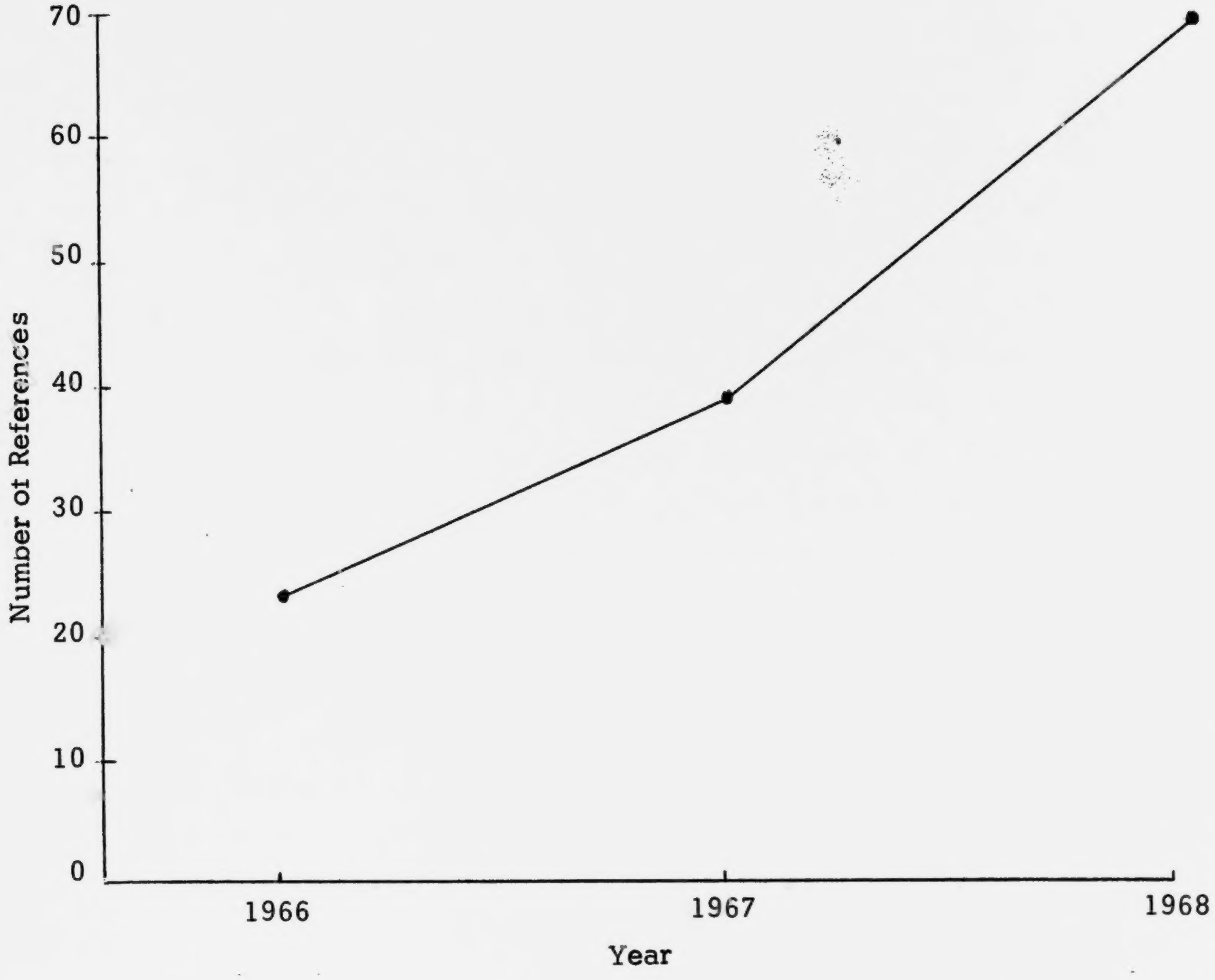
Knowledge of project-related attitudes and behavioral characteristics of university scientists is critical as an input to system planning for at least four reasons. First, information about scientists' attitudes serve as a major source of constraints in system planning. The decision task of allocating research project functions to either the scientist subsystem or the service subsystem, or to both for joint accomplishment, is significantly influenced by the motivations and desires of the scientists themselves. The scientist, for political and professional reasons, may choose to perform certain research functions even though the performance of these activities is within the technological state-of-the-art and is economically feasible. Second, for those research project functions which have been assigned to the scientist and service subsystems for joint accomplishment, it is important for system design purposes to be thoroughly cognizant of the behavioral patterns shown by scientists in performing the particular research activities involved. The design of the service subsystem should be based on optimizing the dynamic interactions between the scientist and the service subsystem during the conduct of required research tasks and subtasks. Third, for those research project functions which will be accomplished independently by the scientist and service subsystems, the structural and functional input/output interfaces are critical design factors. Both attitudinal and behavioral characteristics are important in guiding the design of input/output components and procedures. Fourth, although the service subsystem should play a dominant role in the performance of a research project, the scientist has traditionally used a number of formal and informal sources of information and supporting services. Whether it would be efficient to shift the full supporting responsibility to the university-based service subsystem is questionable. In any case, it is necessary to identify these various sources and services and to describe how and under what conditions scientists utilize them during the conduct of a grant-supported research project. Information of this nature will help establish the scope and boundaries of the service subsystem.

A review of relevant literature on the research-related behavioral characteristics of scientists shows a rapid increase during the past few years concerning scientist information needs and uses. A gross measure of this increasing emphasis on the study of scientist information needs and uses is shown in Figure 7. Menzel, in Volume 1 of the Annual Review of Information Science and Technology (20), summarized the findings of 23 studies which dealt with the topic of scientist information needs and uses. The literature spanned the period 1963 through 1965. Saul and Mary Herner (1967) in Volume 2 (21) cited 38 studies covering, for the most part, 1966. Paisley (22) cited 68 relevant studies covering primarily 1967. In spite of variations in length of time actually covered in the Annual Reviews, and possible differences in the review thoroughness of the authors, the size of the differences shown in Figure 7 suggests that there is an increasing interest in the problem of determining scientist information needs and uses as inputs to system planning. Along with the attention being given to the problem, there has been a strong trend toward improving the methodology employed in studying the information need problem and a beginning trend toward developing an adequate conceptualization of the user and his information needs.

The wide ranging studies on scientist information needs and uses have utilized questionnaires, direct observation, interviews,

Figure 7

Number of References on Information Needs and Uses Cited in the Annual Review of Information Science and Technology



diaries, laboratory experiments, and on-line information systems to investigate information needs and uses. University, non-profit organizational, laboratory, and industrial settings have been used. The types of behaviors studied have included research project related behaviors, characteristics of personal indexes, oral/informal technical communications, and behavioral characteristics associated with formal sources and types of information (20, 21, 22, 26, 31, 34, 35, 42, 54, 62, 75, 76, 77).

In reviewing the literature on information needs and uses, two related observations seem relevant. First, although increasing interest and methodological sophistication is being shown in the problem area, and the amount of data and findings being generated is increasing, it is not clear just how the system planner can use this growing wealth of information in helping to design an information system. It is assumed that a primary, if not the sole, objective of most of these studies is to contribute to system design. If so, it would seem that a great deal of effort would be made to show specifically how the findings should influence or at least be relevant to system design. As Van Cott and Kinkade (95) point out in a recent report there is a need for bridging the gap between so-called user studies and system design requirements studies.

A second and related observation concerns an apparently common assumption that to achieve valid data for system planning and development purposes, it is necessary that the study be undertaken using real or prototype systems capable of meeting the information needs of real users functioning in a realistic environment. This assumption seems to be rather commonly held by those involved with computer based information systems. However, the high cost involved in using fairly large prototype or experimental test beds for research purposes raises a point for consideration. If specific system design related questions covering information needs and uses can be clearly articulated, we may find that the answers to a significant number of these questions can be obtained through less expensive means. And, even though there may result a general consensus that real or prototype systems represent the optimum setting, the task of clearly identifying and articulating the design-related questions is an important requirement in its own right.

Figure 8 illustrates, at a very gross level, how findings concerning research related attitudes and behaviors of scientists could have system planning implications. Inspection of Figure 8 suggests that primary responsibility for performing research tasks and subtasks requiring scientific capabilities will be done largely by the scientists or jointly by the scientist and the subsystem. This will undoubtedly be the case with those tasks requiring creative abilities, for example, developing hypotheses and designing data collection equipment techniques. On the other hand, it is reasonable to assume that a number of the straight forward tasks, for example, computational tasks, can be allocated to the service subsystem for accomplishment. With respect to those tasks requiring information retrieval and the organization of information, the service subsystem likely will be assuming a greater degree of responsibility as the size of the pool of relevant information increases, and concomitantly as the ability of the scientist to keep abreast of the relevant literature "on his own" decreases. Finally, the scientist might willingly leave to the service subsystem the tasks requiring both clerical and resource management skills and knowledge.

Figure 8

Scientist Attitudinal and Behavioral Characteristics
With Respect to Research Project Requirements

| Research Project Requirements<br>Scientist Characteristics | Scientific | Informational | Managerial |
|---|---|---|---|
| Attitudinal | Strong personal identification for political as well as professional reasons | Increasingly mixed feelings and preferences as the requirement grows | Often viewed as a necessary evil |
| Behavioral | Primary reliance on formal means and own capabilities, that is, methodological and subject matter requirements | Utilizes both formal and informal means, that is, colleagues, publications, and conventions | Primary reliance on learning by experience |

## I. Environmental Constraints and Contributions

The scientist and his research-related attitudes and behaviors have been considered. Now the attitudes and behaviors of various environmental sources as they pertain to the research project will be considered. These environmentally originating attitudes and behaviors are translatable into system planning constraints, requirements, and supporting services.

As pointed out in the preceding section, while an increasing amount of attention is being devoted to the scientist, at least with regard to his information needs and uses, there is little known about the viewpoint of the environment in which the scientist functions. With the notable exception of current interest in the question of federal funds for basic research, searching the available literature has turned up little information directly relevant to this question.

Nevertheless, the importance of the research environment is well recognized as shown by the information obtained during visits to universities where computer-based information systems are being developed. See Appendix B for a summary of the information obtained during visits to the selected universities. Comments of individuals interviewed during these visits highlight the criticality of the environment. In reports which discuss scientist information needs and uses, statements about the environment also point up this criticality. As an example, Paisley (22) in the 1968 Annual Review of Information Science and Technology identified eight different external contexts that are critical with respect to the scientist information needs and uses. These eight contexts include the scientist within his work team, within a formal organization, within an invisible college, within his reference group, within a membership group, within a formal information system, within a political system, and within his culture. However, these different external contexts are usually viewed from the perspective of scientist rather than from the perspective of the environment.

Figure 9 illustrates the role of the environment as a source of system planning constraints, requirements, and research support. The information contained in the cells is largely conjectural, like the information in Figure 8, but it should help as a vehicle of communication. Environmental sources are grouped under university-based entities and entities external to the university. Within the university environment, there exist facilities for supporting research, professional faculty and staff, and the administrative officers and staff. Within the external environment, the research project sponsor is included, and journal editors and staff members for professional conventions, and scientists/engineers who are members of the general professional community are also included. The column headings depict the major kinds of skills and knowledge required to plan, conduct, and document a grant-supported research project. The information presented in Figures 8 and 9 are intended to convey two major points. First, the so-called attitudes and behaviors of the scientist and the environmental agencies are directed to a common object; that is, the research project functions or requirements. It is these research project functions which will be allocated to the scientist or service subsystem, and it is these functions around which the system will be planned and designed. Second, the different environmental agencies provide the system planner with a source of system planning constraints, requirements, and support. The service facilities, the professional faculty/staff, and the professional community provide administrative and technical support for the research project. The university administration provides constraints in terms of policies and procedures. The sponsor provides support in the way of funds and information and requirements, and the journal editors/ convention staff provide requirements of a scientific, informational,

**Figure 9**

Environmental Constraints and Contributions

| Environmental Sources | | Scientific | Informational | Managerial |
|---|---|---|---|---|
| University Environment | Service Facilities | Provides computational and laboratory-related services | Provides library-related services | Provides clerical services and administrative resources |
| | Professional faculty/staff | Provides a locally available professional and technical sounding board | Provides sources for relevant literature and relevant chunks of information | Not applicable |
| | Administrative Officers/Staff | Establishes policies related to professional requirements and practices | Establishes policies and procedures related to information gathering activities including library, travel, telephone | Establishes policies related to resource allocation and clerical support |
| External Environment | Research Project Sponsors | Degree of guidance covering the boundaries of the proposed research project | Provides information on problem areas of high interest and the identification of other scientists with common interests | Provides fiscal support and establishes administrative requirements and guidelines concerning the support |
| | Journal Editors/Referees, and Professional Personnel who review and approve convention papers | Provides basic publication standards covering technical requirements | Provides basic publication standards covering supporting literature requirements | Provides basic standards covering clerical and format requirements of an article/presentation |
| | Professional Community of Scientists/Engineers | Provides formal methodological and subject matter inputs | Provides descriptions of completed research studies and findings via formal and informal means | Not applicable |

Research Project Requirements

and managerial nature. In what ways these different constraints, requirements, and services influence system planning will be described in the next chapter.

# CHAPTER III

# TECHNICAL DESCRIPTION

# III. Technical Description

## A. Introduction

The role of the preceding chapter was to identify functional types of information needed as inputs to system planning and development decisions. The role of this chapter is to identify basic types of system-related decisions and to discuss how functional and technical inputs are used to help resolve these decisions.

The following summary statements on scope and orientation provide a context for discussing system-related decisions.

. The task-oriented systems of concern are restricted to advanced computer-based, on-line, remote access, time-sharing systems.

. The alternative hardware and software system concepts, configurations, and components considered as potential candidates for the task-oriented systems are within the technological state-of-the-art.

. The task-oriented R-P System described in this report is composed of two so-called independent subsystems, a scientist subsystem, and a service subsystem. The full range of tasks and subtasks required of grant-supported research projects are to be performed by the scientist and service subsystems either separately or jointly.

. The orientation adopted in this report is that the service subsystem should either separately or jointly with the scientist subsystem assume primary responsibility for as many research project subtasks as possible. It is recognized, however, that a number of constraints will prohibit the attainment of this idealized goal. These constraints include cost, technology, professional and political considerations, and the current inability to adequately identify and describe the inputs, processes, and outputs associated with some of the research project subtasks; particularly, those subtasks requiring creative and interpretative skills and knowledge.

. The service subsystem should be capable of performing or contributing to the performance of a wide range of research project subtasks requiring capabilities in the informational, managerial, and scientific areas.

. The computer-based system of concern to this report is that which is either located on the university campus or accessible through remote input/output devices. In either case, the system-provided services are administratively supported by the university.

This chapter introduces and discusses four basic types of system planning and development decisions. One of the basic decision requirements is to achieve an optimum allocation of research project functions to either the scientist subsystem, the service subsystem, or to both subsystems for joint accomplishment. A second decision requirement is to achieve an optimum selection of a system concept; the third involves the selection of an optimum configuration or configurations of types of hardware, personnel, and software for the chosen system concept; and fourth, the selection of optimum components, that is, specific hardware, personnel, and software for the identified optimum system configuration(s).

In resolving these four basic decisions, the types of information identified in the preceding chapter will be used as inputs. The information inputs may be grouped into one of two categories--functional requirements and constraints. The functional requirements category includes (1) the identified research project tasks and subtasks and variations associated with the methodological paradigms, (2) the inferred set of skills and knowledge or performed capabilities needed to perform the research project tasks and subtasks, and (3) the standards or criteria used to evaluate the completed research project. The constraint types of inputs include (1) data on the attitudes and research-related activities of the scientists across all disciplines, and (2) data on the structural, operational, temporal, and fiscal constraints arising from the university environment.

The remainder of this chapter is divided into two major parts. The first part describes a decision model used as a framework for processing the system planning and development decisions. This part, described under Section B, includes an identification of the elements which make up the model, the grouping of these elements under four basic types of decisions required during system planning and development, and a general description of how these elements function during the process of decision making. The second part describes in greater detail each of the four basic system planning and development decisions. Each of the four sections in the second part includes identification of the decision problem to be solved, the types of alternatives to be considered, the required inputs for each type of decision, the criteria for resolving the decision, the nature of the decision output, and the process involved in successively screening, evaluating, and eventually selecting one of the proposed alternatives. Sections C through F cover this second part.

## B. Decision Model

The decision model presented in this section was developed to serve as an aid for identifying, structuring, and resolving major decisions associated with initially screening possible system alternatives, evaluating the remaining feasible system alternatives, and eventually selecting an optimum system. The elements of the decision model are introduced and described using university-based, grant-supported research projects as the assigned system task. Although the substantive parts of the decision model encompass grant-supported research projects, the basic framework should be considered as generally applicable to other tasks which are concerned with information and data processing.

The decision model is responsive particularly to two of the trends noted in Chapter I of this report; (1) the growing numbers of alternative system concepts, configurations, and components from which to choose in planning a computer-based system and (2) the diversity of orientations or perspectives associated with this selection process; that is, the system designer/developer, the system operator/maintainer, the system buyer and the system user. In response to the two trends noted above, the form selected is a graphic construct of the decision process. A simplified version of a cost/benefit decision model is presented in Figure 10. This graphic illustration shows that the decision model is composed of three major parts: the input segment which consists of characteristics or properties of the system inputs and information on constraints and requirements associated with the system outputs; the decision process, which consists of both the alternatives to be considered and the criteria for screening and evaluating these alternatives; and the output segment, which consists of selected and rejected alternatives.

For each of the four basic decisions identified above, there are three steps (see Figure 11). These steps are arbitrarily labelled as the constraint step, the feasibility step, and the selection step. The rationale underlying the three steps is based on a strategy of eliminating proposed alternatives according to a procedure which minimizes the requirements for cost and effectiveness data. That is, data involving the performance and cost characteristics associated with each proposed alternative. The constraint step represents a go/no-go condition for the proposed alternatives (see Figure 12). Only those alternatives which are judged to be compatible with respect to the various established constraints

Figure 10. A Simplified Illustration of the Cost/Benefit Decision Model

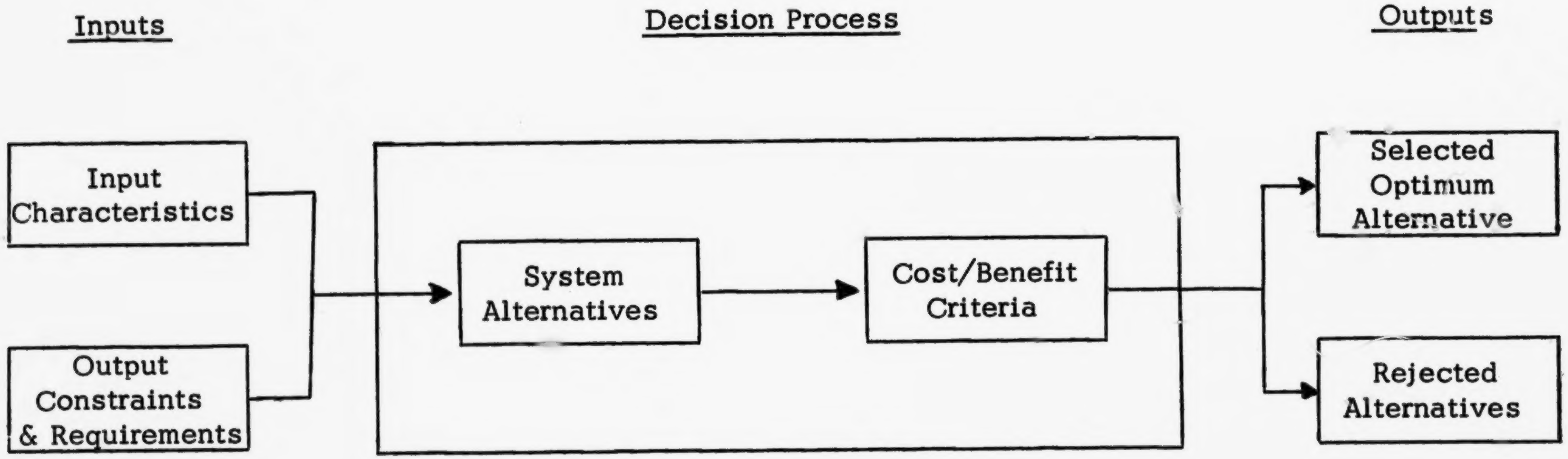

Inputs
Decision Process
Outputs
Input Characteristics
Output Constraints & Requirements
System Alternatives
Cost/Benefit Criteria
Selected Optimum Alternative
Rejected Alternatives

Figure 11. Scheme for Reducing Possible System Alternatives to the Selected Optimum Alternative

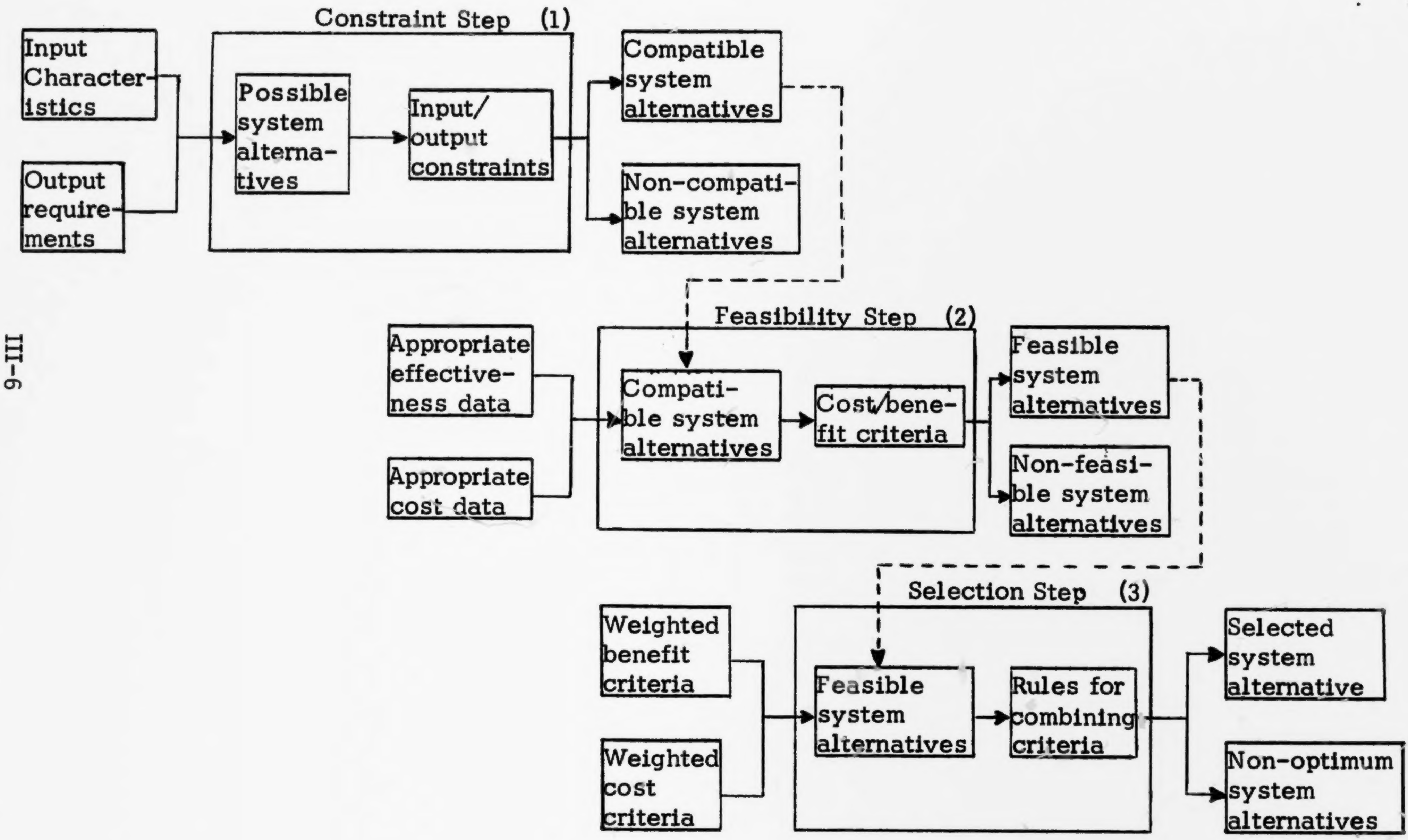

Constraint Step (1)
Input Characteristics
Output requirements
Possible system alternatives
Input/ output constraints
Compatible system alternatives
Non-compatible system alternatives
Feasibility Step (2)
Appropriate effectiveness data
Appropriate cost data
Compatible system alternatives
Cost/benefit criteria
Feasible system alternatives
Non-feasible system alternatives
Selection Step (3)
Weighted benefit criteria
Weighted cost criteria
Feasible system alternatives
Rules for combining criteria
Selected system alternative
Non-optimum system alternatives

Figure 12. Relationship of Criterion Values, Weights, and Rules to the Nature of the Decision

| Decision Nature | Criterion Values, Weights, and Rules |
|---|---|
| Screen to identify compatible alternatives<br>(Step I) | Assign go-no go values to constraints |
| Evaluate to select feasible alternatives<br>(Step II) | Assign minimally acceptable and maximally allowable values to relevant cost/benefit criteria |
| Weight criteria to select the optimum alternative<br>(Step III) | Assign weights to criteria to reflect their relative importance and devise a rule for combining the weighted criteria |

are considered as candidates for the next or feasibility step. These constraints can be political, professional, technological, organizational, environmental, or cost in nature. The goal is to separate as quickly and inexpensively as possible compatible from incompatible alternatives. The second step, labelled the feasibility step, serves as a screen for the remaining compatible alternatives. Those compatible alternatives which either do not meet established minimum performance levels or exceed maximum cost levels are eliminated from further consideration. The selection step - the final step - involves the weighting of both cost/benefit criteria with respect to relative importance and the application of a rule for combining the weighted criteria to arrive at an optimum alternative. As one progresses from the constraint step to the selection step, data required on cost and effectiveness of each alternative increases in both degree of specificity and in volume. For this reason, the procedure shown in Figure 11 is designed to minimize the cost and performance data requirements while at the same time insuring that all possible alternatives are treated as potential candidates for the task-oriented system.

## C. Allocation of Research Functions

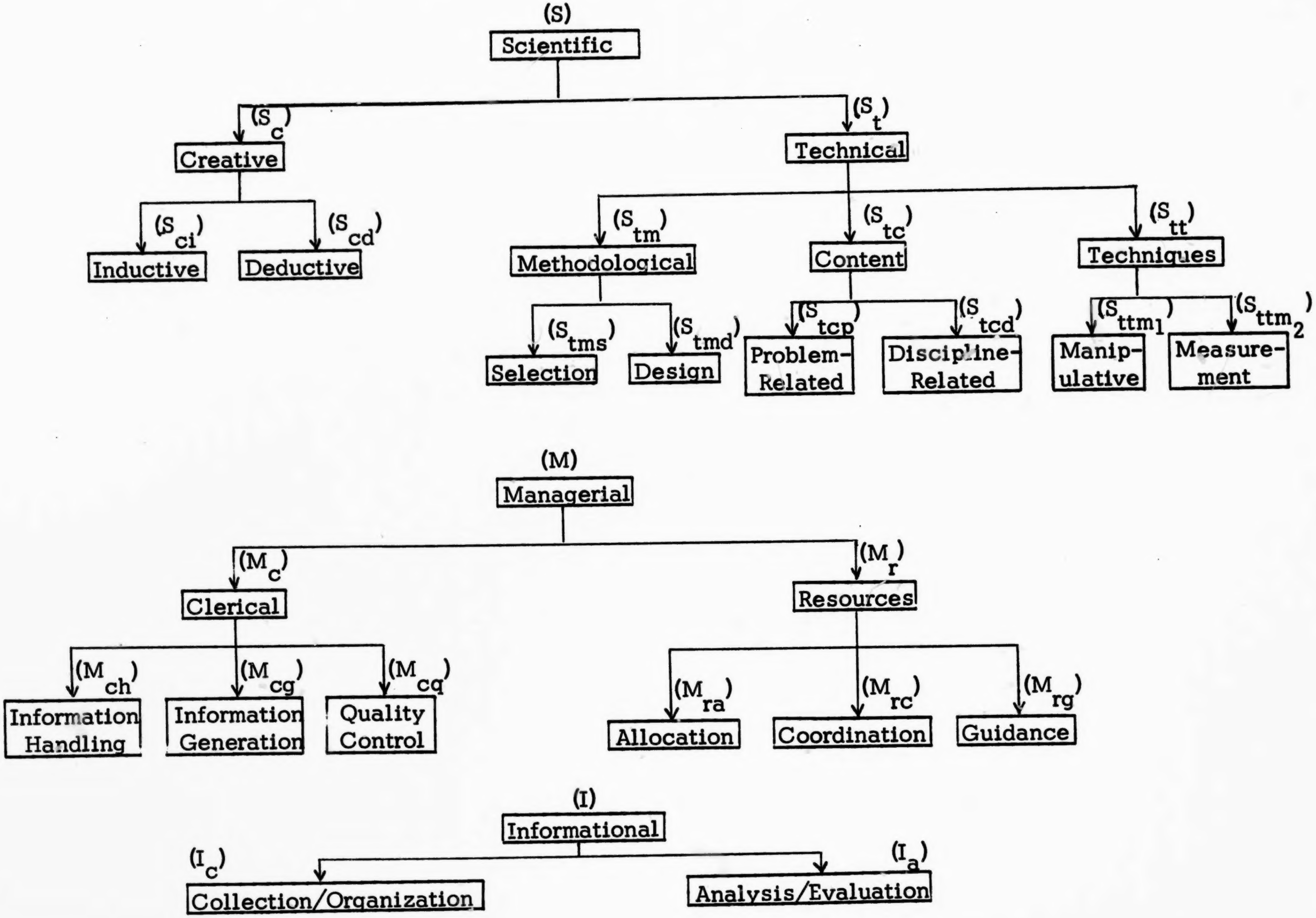
A decision that must be resolved during the very earliest period in system planning concerns the allocation of job functions. Which functions will be the primary responsibility of the new system and which functions will remain the primary responsibility of the existing system is the nature of the decision problem. Here, the decision task is one of determining which research project functions the service subsystem will perform separately or jointly with the scientist and which functions, if any, the scientist will continue to perform. As noted earlier, the orientation adopted in this report is to assign to the service subsystem primary responsibility for performing or contributing to the performance of as many research functions as possible.

The allocation decision differs from the other three basic system planning and development decisions in a number of ways. First, it is concerned with the scope and performance boundaries of the service subsystem rather than with the nature or structure of the service subsystem, as are the other three decisions. Second, the process of allocating research functions is achieved totally by use of go/no-go constraints rather than criteria which can assume a number of values along various cost and performance scales. It is possible to pictorially characterize the process as one in which the system planner starts by assuming that the service subsystem will perform all of the grant-supported research functions. Then various filters, constraints, are used - constraints such as university policies, scientist research-related activities, and computer state-of-the-art - such that the end result of the filtering process results in three groupings: those functions that are assigned to the service subsystem, those functions that will be jointly accomplished by the scientist and service subsystem, and finally, those functions that remain the responsibility of the scientist. Third, the outcome of the decision process does not lead to the rejection of some of the alternatives as with the other three decisions. The decision task is not concerned with accepting versus rejecting but with allocating responsibility. Although the allocation type of decision is different, to preserve a structural and functional commonality throughout, the format used as a guide for allocating research functions is similar to the one used for the other three classes of decisions.

What are the research functions to be allocated? In the preceding chapter three primary types of skill and knowledge requirements were identified: scientific, managerial, and informational. An analysis of the research project subtasks led to "factorization" of these three main types of skill and knowledge requirements into 16 research subfunctions. These research functions comprise the kinds of performance capabilities required to satisfactorily plan, perform, and document a grant-supported research project. Figure 13 presents the results of this preliminary analysis.

Examination of Figure 13 shows that there are eight scientific categories, six managerial categories, and two informational categories. The scientific category is divided into creative and technical requirements. Creative requirements are further subdivided into inductive and deductive skills. The inductive category includes those research activities which emphasize the requirement for generalizing from a specific empirical data base to a more general theoretical base; while the deductive category emphasizes the skills associated with deducing or hypothesizing specific testable consequences or outcomes from a broader theoretical base. Subtasks involving hypothesis formulation and hypothesis delineation fall into the creative category as well as the problem of interpreting research findings. The technical category is divided into methodological capabilities, content knowledge, and technique skills. Methodological requirements are further subdivided into those labelled as selection, design, and analysis. Selection includes those required capabilities associated with selection of such elements of a research project as a study setting (laboratory versus field), selection or development of criteria, selection of conditions, selection of experimental subjects, and selection of appropriate analyses to perform on the data. Design, on the other hand, deals with the procedural characteristics of a research project. The design category includes how and when certain events will be manipulated or controlled, or measured, or sampled, or the data analyzed. While selection is concerned primarily with the

Figure 13. Research Project Functions


(S)
Scientific
($S_c$)
Creative
($S_{ci}$)
Inductive
($S_{cd}$)
Deductive
($S_t$)
Technical
($S_{tm}$)
Methodological
($S_{tms}$)
Selection
($S_{tmd}$)
Design
($S_{tc}$)
Content
($S_{tcp}$)
Problem-Related
($S_{tcd}$)
Discipline-Related
($S_{tt}$)
Techniques
($S_{ttm_1}$)
Manipulative
($S_{ttm_2}$)
Measurement
(M)
Managerial
($M_c$)
Clerical
($M_{ch}$)
Information Handling
($M_{cg}$)
Information Generation
($M_{cq}$)
Quality Control
($M_r$)
Resources
($M_{ra}$)
Allocation
($M_{rc}$)
Coordination
($M_{rg}$)
Guidance
(I)
Informational
($I_c$)
Collection/Organization
($I_a$)
Analysis/Evaluation

identification of what will be investigated and where, design is concerned with how and when the investigation will be conducted and the findings processed. Subject matter content is subdivided into those items of required knowledge (stored information) which are specifically problem-related versus those required items of knowledge which are more generally discipline-related. Finally there are subtasks which emphasize manipulative skills and knowledge versus those requiring measurement skills.

The managerial category is divided into clerical and resource management requirements. Clerical categories include information handling such as filing, organizing, coding, and compiling; information generation such as typing, writing, displaying, etc.; and quality control such as detecting errors of omission and commission, and editing. The resource management category includes (1) the allocation of resources; that is, personnel, facilities, equipment, and money to accomplish different parts of the research project, (2) the coordination or utilization of the resources over time through scheduling, and (3) the provision of necessary guidance or instructions to participating research staff members to insure efficient conduct of the research project.

The informational category pertains to those subtasks which involve the acquisition of information from external sources and the processing of this information. This includes all subtasks requiring bibliographic types of activities, the reviewing, screening and extracting/tagging of relevant chunks of information, and analysis of these "chunks of information". The informational category is divided into the collection/organization subcategory and the analysis/interpretation subcategory. The former includes all subtasks which involve the more mechanical aspects of information processing while the latter refers to the more intellectual and analytical activities associated with information processing.

Figure 14 provides a framework for grouping subtasks by skill and knowledge categories for each phase of the research project and for each of the four methodological paradigms. It can be seen in the figure that different skill and knowledge categories are employed in the detailed planning phase depending on the methodological paradigm selected. Figure 14 may be used also to point out that as the system planning and development activities progress, the size of the data base grows exponentially. Therefore, it becomes increasingly important to classify and organize system-related information and data. The system data base is used as inputs to decision making and as a source of information to facilitate the development of alternative system concepts (64,79).

Figure 15 illustrates that three successive screening steps or types of constraints are used to guide the allocation process. The initial screening step utilizes functional types of constraints to help determine which research functions will be potentially the primary responsibility of the service subsystem, the joint responsibility of the scientist and service subsystem, or remain the responsibility of the scientist. The major functional constraint concerns present limitations on being able to adequately define all of the required tasks and subtasks associated with grant-supported research projects. Those tasks and subtasks which cannot be adequately identified and described must necessarily remain, for the time being, the primary responsibility of the scientist. A secondary constraint involves professional and/or political views held by the population of scientists in question. An overwhelming majority of the scientists may, for professional or political reasons, insist that the performance of certain research subtasks remain their primary responsibility. However, it is recognized that attitudes of individuals, including scientists, are subject to change with increasing opportunity to share in the benefits of modern technology.

Figure 14. System Planning Data Base: Detailed Planning

| Paradigms / Phases | Experimental | Statistical | Observational | Modeling |
|---|---|---|---|---|
| I Proposal Preparation | | | | |
| II General Planning | | | | |
| III Detailed Planning | Subtasks $III_N$ - $III_{N+n}$ ($S_{tmd}$) | Subtasks $III_N$ - $III_{N+n}$ ($S_{tms}$) | Subtasks $III_N$ - $III_{N+n}$ ($S_{ttm_2}$) | Subtasks $III_N$ - $III_{N+n}$ ($S_{cd}$) |
| IV Data Collection | | | | |
| V Analysis/ Interpretation | | | | |
| VI Report Preparation | | | | |

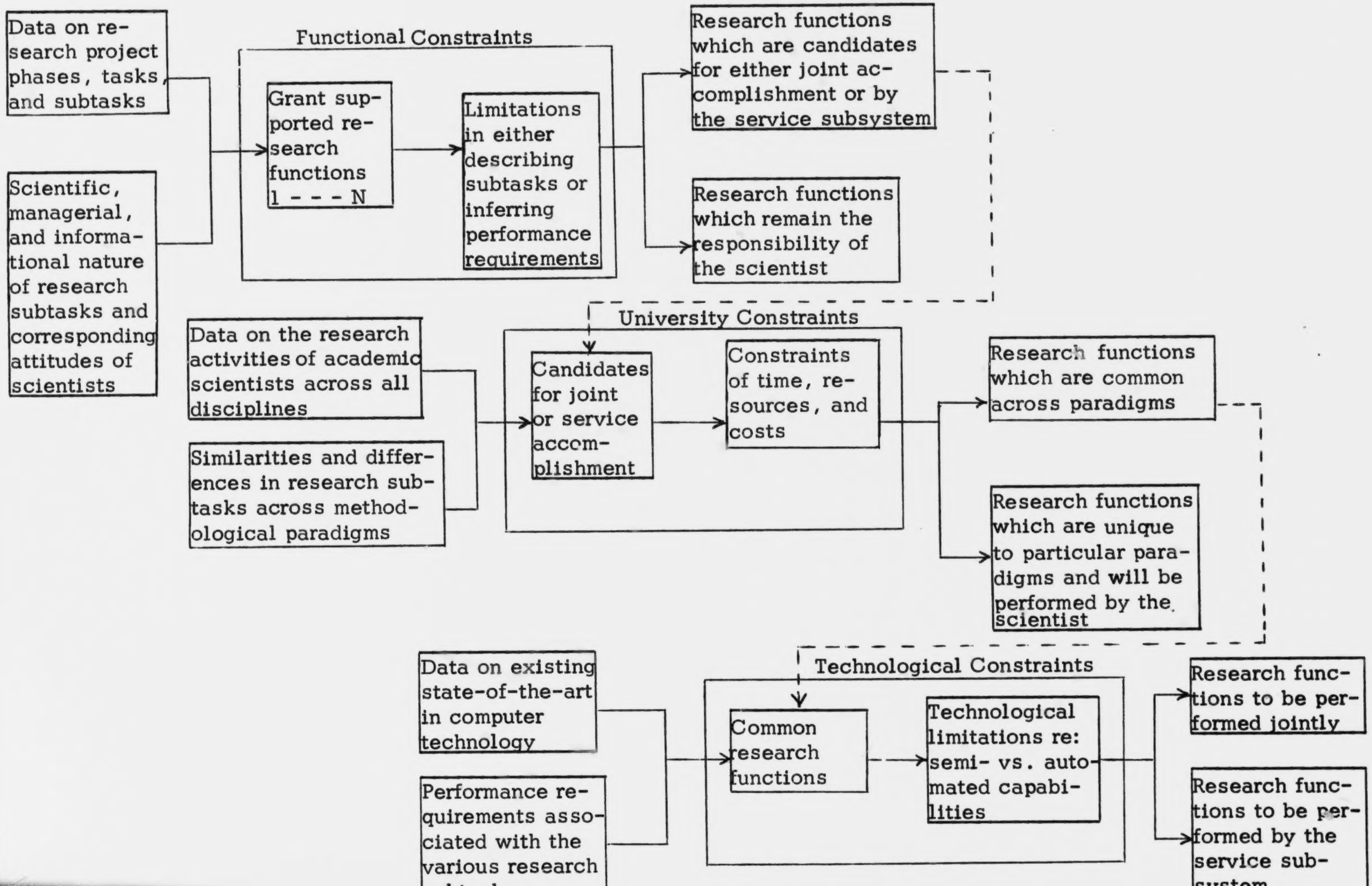


Figure 15. The Allocation of Research Project Functions

Data on research project phases, tasks, and subtasks
Scientific, managerial, and informational nature of research subtasks and corresponding attitudes of scientists
Functional Constraints
Grant supported research functions 1 - - - N
Limitations in either describing subtasks or inferring performance requirements
Research functions which are candidates for either joint accomplishment or by the service subsystem
Research functions which remain the responsibility of the scientist
Data on the research activities of academic scientists across all disciplines
Similarities and differences in research subtasks across methodological paradigms
University Constraints
Candidates for joint or service accomplishment
Constraints of time, resources, and costs
Research functions which are common across paradigms
Research functions which are unique to particular paradigms and will be performed by the scientist
Data on existing state-of-the-art in computer technology
Performance requirements associated with the various research
Technological Constraints
Common research functions
Technological limitations re: semi- vs. automated capabilities
Research functions to be performed jointly
Research functions to be performed by the service sub-

For this reason, and because it is consistent with the task-oriented approach, less weight is placed on attitudes as a system constraint than on the ability to articulate research tasks and subtasks. The second filtering step utilizes what might be conveniently labelled as 'university' constraints. Specifically, the problem is to separate research functions which are unique to particular paradigms. These unique research functions will be retained by the scientist and support staff (e.g., a secretary) for primary accomplishment. The obvious purpose of this filtering step is to retain only those functions for further system planning activities which are judged to be worth spending time and money. That is, functions which are common to a wide range of academic scientists. The final screen on the remaining functions is a technological one. The general state-of-the-art in computer technology serves as a constraint. In the context, the phrase, "state-of-the-art" is taken to mean "off-the-shelf" variety rather than theoretically possible or even research-demonstrated state-of-the-art capable. It is recognized that special computer software programs will need to be developed and that items of hardware will need to be combined in perhaps unique ways. However, these fabrication types of activities do not require research and development (R&D) effort in the commonly understood sense of R&D. During this filtering step, the question is whether the service subsystem can assume primary responsibility for accomplishment of the remaining functions or whether - due to current limitations in computer technology - the scientist must continue to perform certain parts of the research functions and the service subsystem the remaining parts.

## D. Selection of a System Concept

The goal of this system planning activity is to select from among proposed alternatives a concept which is optimum with respect to managerially oriented cost/benefit criteria.

Considering the wide range of scientific, informational, and managerial capabilities needed to perform the tasks and subtasks which make up a grant-supported research project, it is likely that proposed alternative system concepts will differ significantly among each other in terms of both their comprehensiveness in performing the allocated research functions and in the manner in which these functions will be performed. Variability and multiplicity in system concepts is critical if the planning process, as presented in this report, is to possess any utility. The larger the number of innovations proposed, the more likely there will be system concepts which differ radically in their characteristics. Trade-offs will be required between numbers and kinds of research functions to be included within the various system concepts. For example, one system concept might maximize on those research functions of an informational nature in contrast to the scientific or managerial functions. As another example, primary attention might be devoted to a system concept which emphasizes performance of research functions which have been allocated to the scientist and service subsystem for joint accomplishment rather than those functions allocated to the service subsystem for primary responsibility. The point to be made is that the diversity and range of functional requirements are sufficiently broad so that it is most probable that alternative system concepts, which are proposed, will vary considerably in their degree of comprehensiveness and emphasis, and in the form they will assume. These variations in alternative system concepts provide the bases by which concepts are compared in terms of various managerial criteria.

Figure 16 presents three managerially-oriented criterion concepts and possible operational definitions for these concepts. As the figure indicates, the primary perspective is that of the system buyer. Individuals, institutions, or organizations which contribute money, time, talent, and/or facilities represent system buyers. In this context

Figure 16. Criterion Concepts and Measures Which Reflect the Managerial Point of View

| Perspective/Criterion Source | Criterion Concepts | Possible Criterion Measures |
|---|---|---|
| R-P system buyer | Growth potential (future use) | Number of system structural, input/output, and performance characteristics which can be modified and the degree of modifiability |
| | Marketability (many users) | Number of subtasks that can be processed within a given period of time or processed simultaneously |
| | Flexibility (many uses) | Percent of total research projects that can be accomplished jointly or by the service subsystem |

growth potential is measured in terms of the modifiability or adaptability of a system with respect to its structural, input/output, and performance characteristics. Since the state-of-the-art in projecting future requirements is debatable regarding its accuracy, a strategy used in system planning has been to design and develop system concepts which are modular or evolutionary in nature. That is, systems are designed to facilitate modifications in their structural, input/output, and performance characteristics. In addition, the trend has been to shift more of the functional requirements from the less modifiable hardware to the more modifiable software or computer programs. The criterion concept of marketability cited in Figure 16 refers to the ability of a system to perform either at the same time or within a given period of time a number of functions. The extent to which the system is available for use by different scientists at the same time increases the feasibility of having more scientists use the system. Remotely accessible, time-sharing system capabilities enhance the marketability of a system in that they permit a number of scientists at different locations to simultaneously perform research activities jointly with the computer. The criterion concept of flexibility pertains to the number of different research project functions that the computer-based system can perform; that is, informational, scientific, and managerial functions.

System concepts are not only screened and evaluated with respect to the management oriented criterion concepts - Growth Potential, Marketability, and Flexibility - but also in terms of projected costs. The total costs incurred in both acquiring and operating a system are included. Theoretically, each proposed system concept can be represented in terms of projected values on each of the three effectiveness dimensions and on each of the two cost dimensions. A hypothetical illustration of three alternative system concepts is presented in Figure 17 (96). The extent to which each alternative varies along the effectiveness and cost dimensions is graphically represented by its distance along each of the vectors. The further out the line intersects the three effectiveness vectors, the higher is the value associated with a particular alternative. In contrast, the further out the line intersects the two cost vectors, the lower is the cost value associated with particular alternatives. By defining cost/effectiveness relationships in this manner, the further out a line intersects a dimension, the more desirable is the outcome. Two important points are illustrated in this figure. First, system criteria which reflect multiple performance requirements and cost constraints are often conflicting. For example, System Concept C, shown in Figure 17, is best with respect to acquisition costs. And, System Concept B is highest in Marketability but poorest in Flexibility. Obviously, not all criteria conflict and the existing technological state-of-the-art contributes a great deal to whether and how much various criteria conflict. As an example, for years high information storage capacity in a computer was likely to be attained at the expense of less rapid information processing rate. Today this conflict is less evident (except at extreme speeds and capacities) because of advancements made in computer technology. Second, the fact that proposed system concepts often differ among themselves with respect to values achievable on different criterion dimensions makes the problem of criterion weighting an important one. Each criterion dimension must be weighted as to its relative importance as a guide in helping to select an optimum alternative (100).

The process of screening, evaluating, and eventually selecting an optimum system concept is portrayed in Figure 18. The first step is to identify and screen out alternative system concepts which are incompatible with either structural properties and operational policies

Figure 17. Profile Illustration Showing the Relationship Between Different System Concepts and System Cost/Effectiveness Criteria

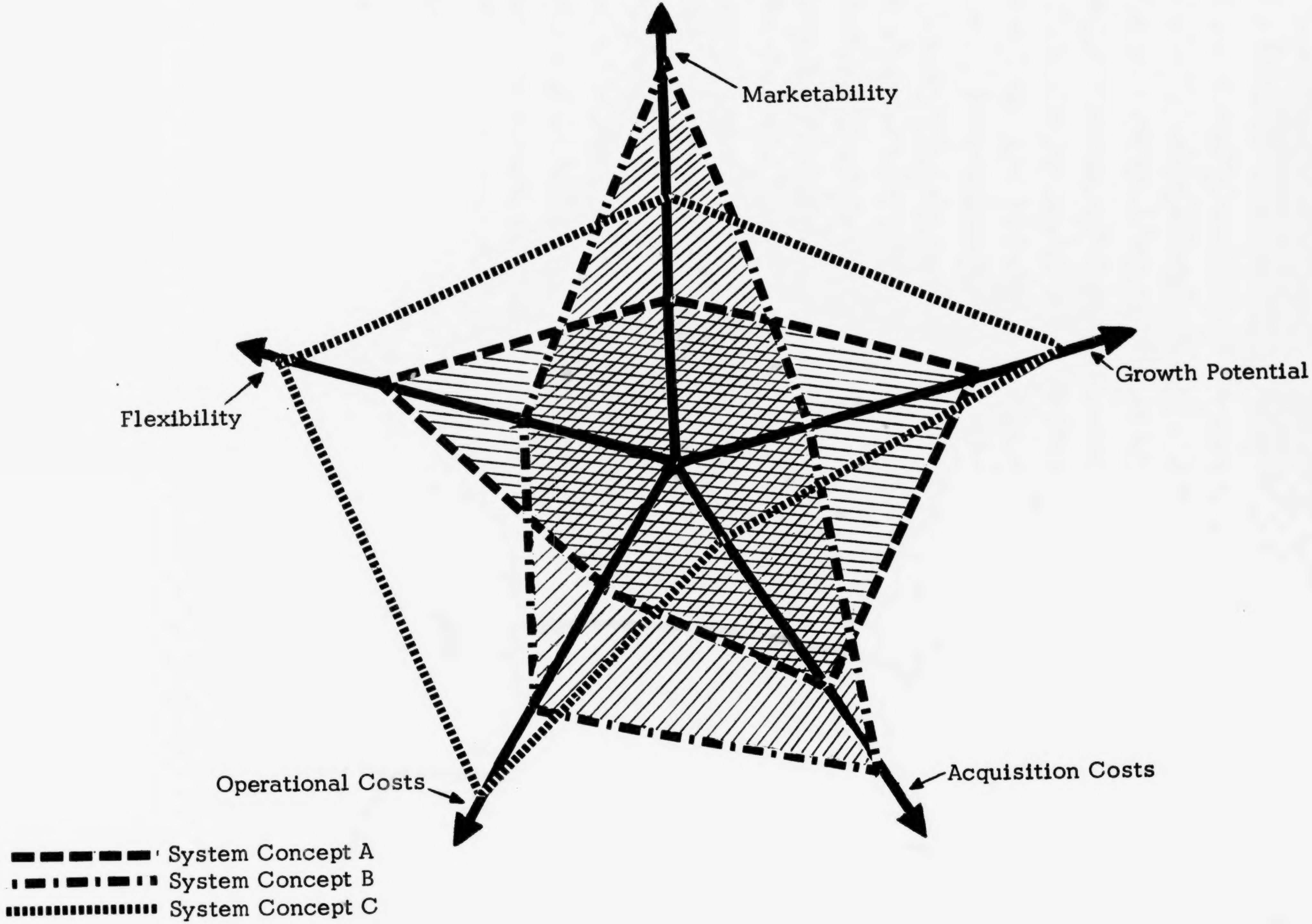
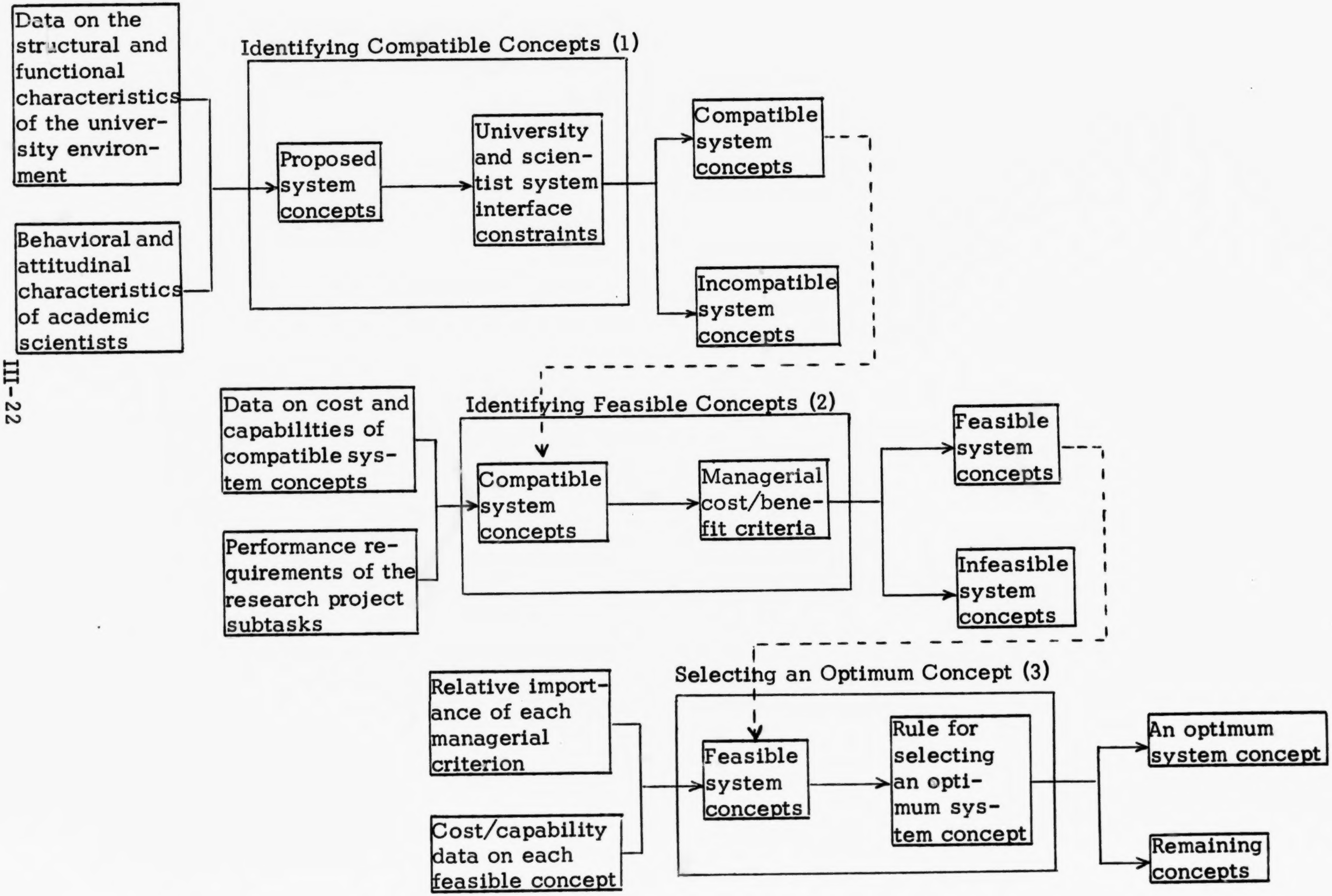


Figure 18. Selection of a System Concept


Data on the structural and functional characteristics of the university environment
Behavioral and attitudinal characteristics of academic scientists
Identifying Compatible Concepts (1)
Proposed system concepts
University and scientist system interface constraints
Compatible system concepts
Incompatible system concepts
Data on cost and capabilities of compatible system concepts
Performance requirements of the research project subtasks
Identifying Feasible Concepts (2)
Compatible system concepts
Managerial cost/benefit criteria
Feasible system concepts
Infeasible system concepts
Relative importance of each managerial criterion
Cost/capability data on each feasible concept
Selecting an Optimum Concept (3)
Feasible system concepts
Rule for selecting an optimum system concept
An optimum system concept
Remaining concepts

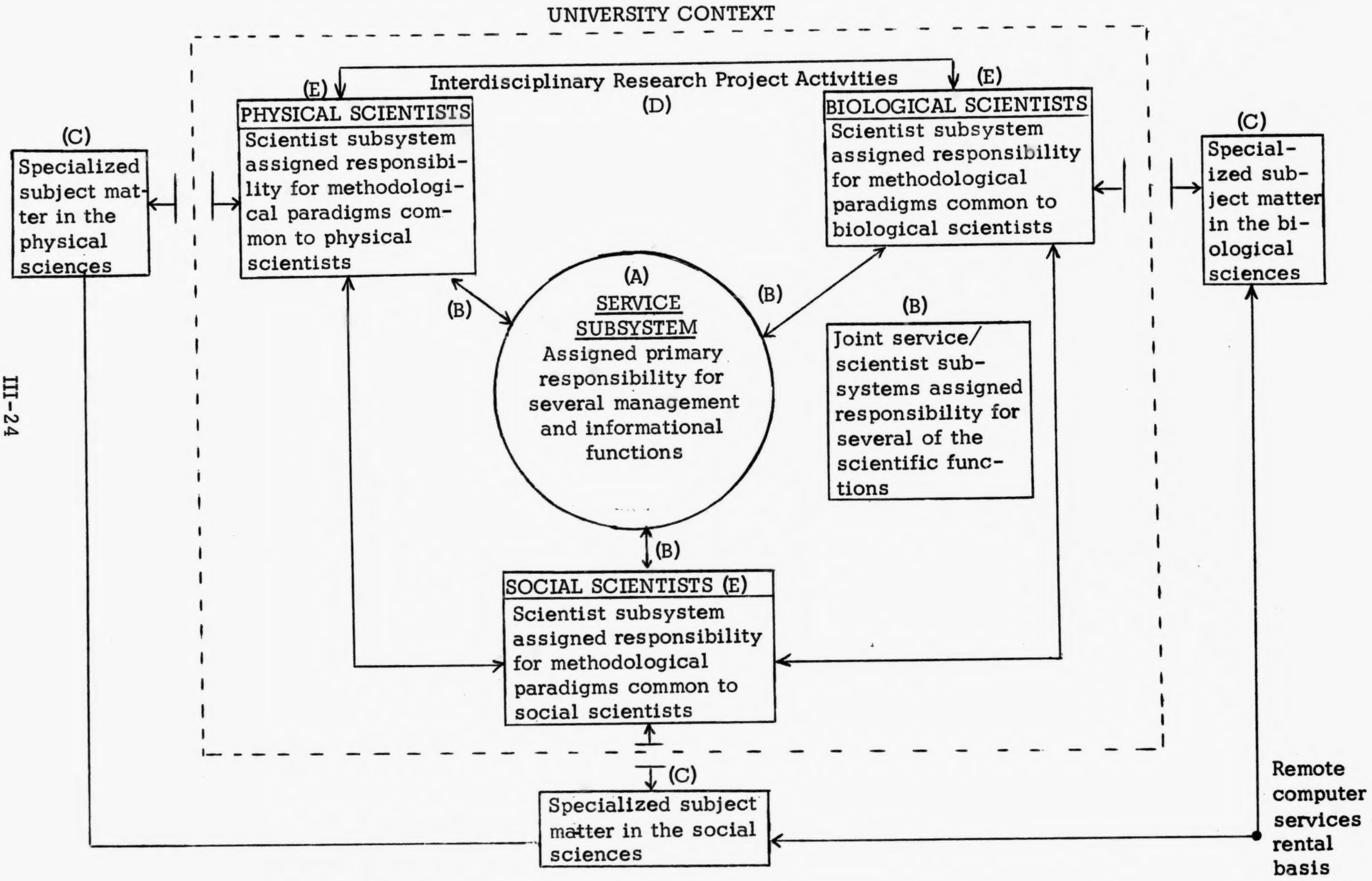
of the university environment in which the system will be located (e.g., building size and air conditioning capabilities) or with the research related behavioral and attitudinal characteristics of the academic scientists. The second step is concerned with screening out remaining alternatives which are found to be infeasible in terms of established cost/effectiveness criteria. The final step involves selecting one alternative which best meets the combined and weighted cost/effectiveness criteria. Obviously, as one alters the criterion values, weights, or rules for combining the weighted criteria, the outcome changes. Making explicit the bases or reasons for these values, weights, and rules is an essential part of the system planning and development process (103).

As an aid in conveying the scope and nature of a system concept, Figure 19 was prepared. This figure presents a simplified graphic version of a hypothetical system concept. There are a number of salient points which should be stressed. These points are briefly described below.

. The system concept recognizes subject matter differences and methodological differences among the physical, biological, and social sciences. In the example shown, these differences led to a three-part structure among the university-based academic researchers. As shown in the figure, a system concept may consist of several structural/functional units. This involves the grouping of functional requirements within various existing organizational and/or structural parts of the university context or whatever platform or context in which a system is being overlaid. In the example shown, there are five structural/functional units. These are identified and described next.

. The portrayed system concept reveals (1) an "allocation" of the required research functions among the different organizational/ structural units and (2) a notion of how these distributed research

Figure 19. A System Concept


UNIVERSITY CONTEXT
Interdisciplinary Research Project Activities
(D)
(E)
PHYSICAL SCIENTISTS
Scientist subsystem assigned responsibility for methodological paradigms common to physical scientists
(E)
BIOLOGICAL SCIENTISTS
Scientist subsystem assigned responsibility for methodological paradigms common to biological scientists
(C)
Specialized subject matter in the physical sciences
(C)
Specialized subject matter in the biological sciences
(A)
SERVICE SUBSYSTEM
Assigned primary responsibility for several management and informational functions
(B)
(B)
(B)
Joint service/scientist subsystems assigned responsibility for several of the scientific functions
(B)
SOCIAL SCIENTISTS (E)
Scientist subsystem assigned responsibility for methodological paradigms common to social scientists
(C)
Specialized subject matter in the social sciences
Remote computer services - rental basis

functions will be performed. For convenience, these five different types of structural/functional units are labelled as system configurations. The five configurations include the computer-based service subsystem (A), the joint scientist-service subsystems (B), the commercially leased services (C), the interdisciplinary teleconferencing network configuration (D), and the discipline-based scientist configuration (E).

. Because the illustrated system concept is made up of five different configurations, the system planner must not only be concerned with the hardware/software/personnel make-up of each configuration but also with the input/output interfaces which functionally and structurally tie the five configurations together into a complete R-P System.

. The graphic system concept furthermore shows that the five configurations have been assigned varying amounts and different types of responsibility for performing the research functions. For example, the service subsystem configuration (A) has a major responsibility for performing several of the managerial and informational functions. Next, the joint scientist/service configuration (B) has been assigned a number of the scientific tasks. The commercial configuration (C) has been assigned responsibility for performing some of the informational functions involving specialized subject matter; the interdisciplinary teleconferencing network configuration (D) is designed to support research projects of a distinctly interdisciplinary nature; and the discipline based scientist-subsystem (E) has been assigned methodological tasks and subtasks which are peculiar to each discipline.

## E. Selection of System Configurations

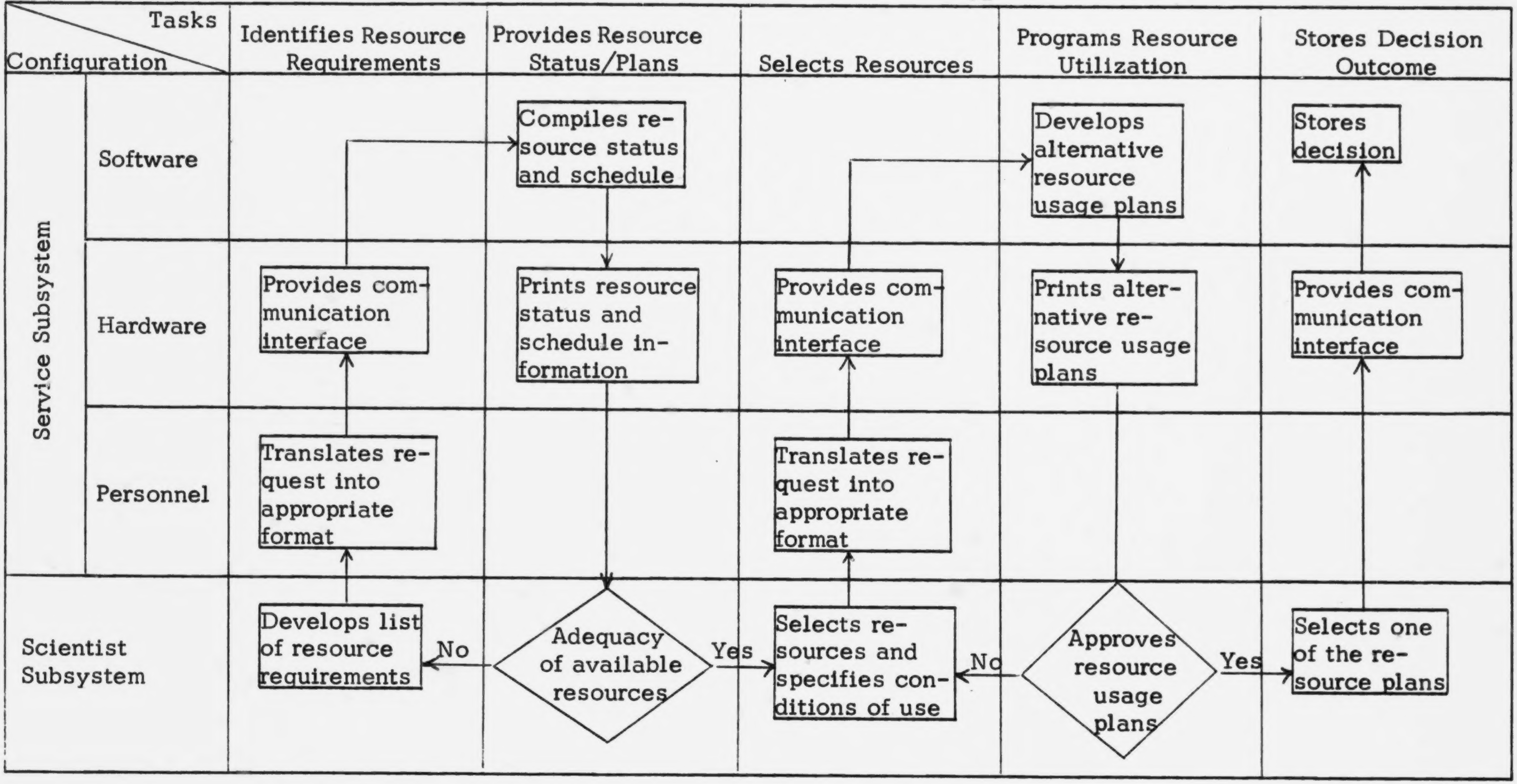
The problems of screening and evaluating system configurations introduces the notion of "process" criteria. Process criteria deal with the functional characteristics of a system. The objective of the decision maker is to select those configurations which (1) most efficiently (performance/cost) perform the various assigned subtasks and (2) are compatible with the inputs and outputs of other configurations which make up the R-P System. Performance of the system configurations is measured in terms of accuracy, speed, and completeness with which each subtask, task, phase, and, ultimately the overall research project is implemented. The operational definition of each criterion measure is a function of the specific characteristics and performance requirements associated with each subtask and task, and the structural and functional properties of the system selected. That is, the type and level of performance needed to satisfactorily complete each part of the research project and the nature of the system dictate both the type of the measure to be used (accuracy in what terms, completeness in what terms, and/or time constraints in what terms), and the level of performance required (how accurate, how complete, and/or how fast) (9, 46).

Acquisition and operational costs are also involved in helping to screen and evaluate proposed configurations. Estimated costs for proposed system configurations should be more specific and reliable than estimates made for system concepts. However, these estimates will still not approach the exactness of component costs and effectiveness estimates simply because, when the selection of components is made, specific components are being considered rather than a type of component (a certain type of person versus a certain type of hardware). The "individual" most interested in meeting the process criteria is the system operator (i.e., the scientist subsystem and service subsystem).

Figure 20 was prepared as an aid in communicating the nature of system configurations. This figure illustrates in a very simplified

Figure 20. Allocation of Managerial Resource Tasks to the Scientist and Service Subsystems

Managerial Resource Allocation Function ($M_{ra}$)



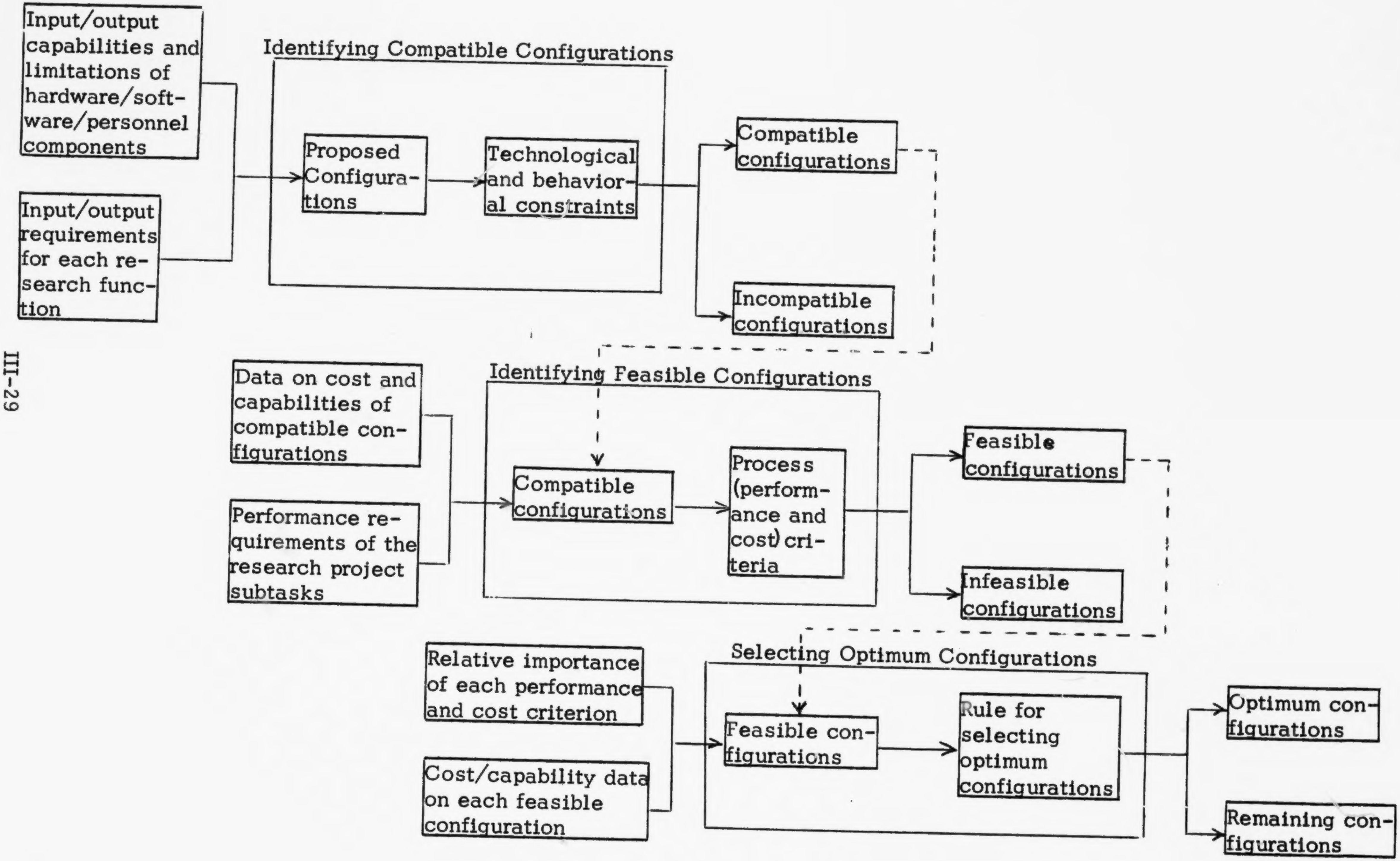
| Configuration \ Tasks | | Identifies Resource Requirements | Provides Resource Status/Plans | Selects Resources | Programs Resource Utilization | Stores Decision Outcome |
|---|---|---|---|---|---|---|
| Service Subsystem | Software | | Compiles resource status and schedule | | Develops alternative resource usage plans | Stores decision |
| | Hardware | Provides communication interface | Prints resource status and schedule information | Provides communication interface | Prints alternative resource usage plans | Provides communication interface |
| | Personnel | Translates request into appropriate format | | Translates request into appropriate format | | |
| Scientist Subsystem | | Develops list of resource requirements | Adequacy of available resources | Selects resources and specifies conditions of use | Approves resource usage plans | Selects one of the resource plans |

manner an outcome of allocating specific task activities to hardware, software, and personnel components. The example shown in the figure identifies which resource management activities have been assigned to what types of components within a given configuration. The figure presents not only the allocation-of-tasks-to-components but also identifies the order in which the activities of each task will be performed and what types of outputs will be transferred from one type of component to another. Performance requirements for each task and its associated activities coupled with the performance capabilities and limitations of each proposed type of component serve as inputs to the evaluation process.

The process of selecting system configurations is shown in Figure 21. Using the example given earlier, there are four structural/functional units for which the system planner is interested in configuring, that is, selecting optimum combinations of hardware/software/personnel. The fifth structural/functional unit is the scientist subsystem who functions as a given in the system design.

The first step in this system planning process is concerned with identifying configurations which have internally compatible input/output characteristics. That is, proposed configurations for each of the different structural/functional units is made up of some mix of hardware/software/personnel components described at a type or broad capability level rather than in terms of specific brand names, individuals, or specific design capabilities. An important requirement is to initially screen out possible mixes or configurations of hardware/software/personnel whose input/output interfaces internal to the configuration are not compatible with respect to the required performance characteristics. Technological (for hardware and software) and behavioral (for human) constraints are used to screen out incompatible configurations. These constraints may be structural,

Figure 21. Selection of System Configurations


Input/output capabilities and limitations of hardware/software/personnel components
Input/output requirements for each research function
Identifying Compatible Configurations
Proposed Configurations
Technological and behavioral constraints
Compatible configurations
Incompatible configurations
Data on cost and capabilities of compatible configurations
Performance requirements of the research project subtasks
Identifying Feasible Configurations
Compatible configurations
Process (performance and cost) criteria
Feasible configurations
Infeasible configurations
Relative importance of each performance and cost criterion
Cost/capability data on each feasible configuration
Selecting Optimum Configurations
Feasible configurations
Rule for selecting optimum configurations
Optimum configurations
Remaining configurations

functional, or operational in nature. This compatibility exercise is required for each of the different structural/functional units which are part of the system concept. In the example shown, the compatibility exercise is required for the four structural/functional units.

The next step is to identify those configurations which meet established performance and cost criteria. Again, the step must be done for all of the system's different structural/functional units.

The final step involves the selection of optimum configurations; one for each of the different structural/functional units. Weighted cost and performance criteria are combined according to a particular rule and applied to each of the applicants. It should be noted that both the performance and cost criteria will likely be different for each of the structural/functional units of the system. Likewise the criterion weighting scheme may change. In some cases the rule for combining the weighted criteria may be altered depending on the criticality and make up of the structural/functional unit in question. The end result of this decision process is a set of optimum configurations of types of hardware/software/personnel components.

## F. Selection of System Components

At this descriptive level in system planning, the number of times that the decision process must be exercised proliferates tremendously. For each configuration, there are generally a number of different types of components. Also, between configurations, there are a number of interfacing input/output components to be selected. It is most critical to screen out, as quickly as possible those components which are found to be incompatible. It will be necessary to gather comprehensive cost effectiveness data as inputs for the subsequent evaluation process for components which survive the initial screening. One technique would be to treat initially those specific components which will contribute to the performance of a number of research activities. It is likely that a number of similar or identical components will be used not only in the same configuration but also in different configurations. If this is the case, much of the available cost/performance data on these components will be applicable more than once in the evaluation process.

The evaluation process is achieved by the use of component cost and "reflexive" criteria. Figure 22 presents alternative reflexive criterion concepts and possible criterion measures applicable to the component selection process. The development of so-called component or reflexive criteria represents a rather complex distillation of both product criteria and system criteria.

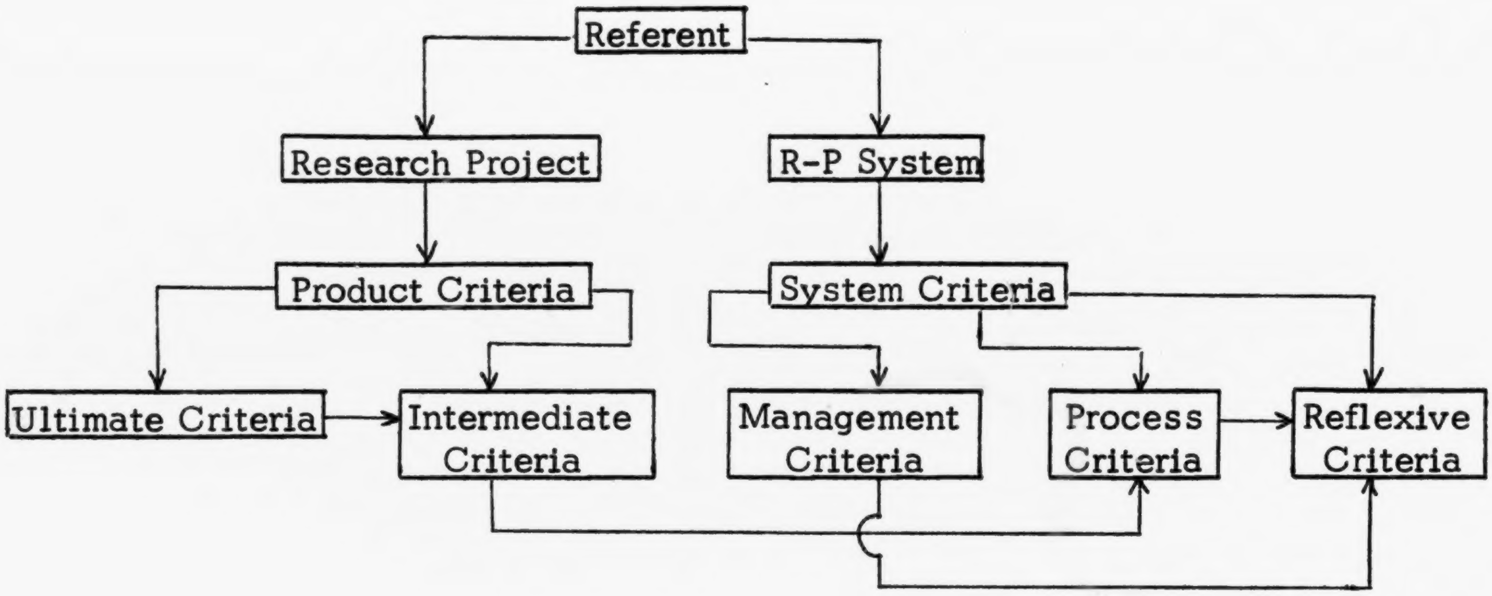
Figure 23 was prepared to graphically summarize the logical analyses required to derive the reflexive criteria. As shown in the figure, the nature and scope of the reflexive criteria are shaped by both the process and managerial criteria. It also shows that the process criteria are derivable from an analysis of the intermediate criteria. The criterion development task is probably the most critical, the most complex, and the less attended to problem in the field of system planning. A report prepared earlier on this project (102) structures and discusses a number of aspects associated with the criterion development problem.

Figure 24 provides a schematic representation of the decision process associated with the screening, evaluating, and eventual selection of system components. Two points are made about this decision process. First, the initial screening process is concerned with identifying components whose design properties are compatible. The question of compatibility in selecting configurations is concerned

Figure 22. Some Possible Reflexive Criterion Concepts and Measures

| Basic Nature of the Criterion | Some Criterion Concepts | Criterion Measures |
|---|---|---|
| Performance (how well) | Precision | Level of accuracy achievable |
| | Sensitivity | Mean number of errors of omission per unit of time |
| | Stability | Mean number of errors of commission per unit of time |
| Availability (how long) | Reliability | Mean (average) time between failures |
| | Maintainability | Mean (average) time to repair |
| | Durability | Range of environmental conditions under which component can still function |
| Utilization (how often) | Capacity | Number of information elements (bits) the component can store |
| | Cycle time | Time to complete a specified operation |
| | Reaction time | The period of time from an action decision to the onset of the ordered action |

Figure 23. Criterion Model: A Summary


Referent
Research Project
R-P System
Product Criteria
System Criteria
Ultimate Criteria
Intermediate Criteria
Management Criteria
Process Criteria
Reflexive Criteria

## A. ULTIMATE CRITERIA (REFERENT IS A COMPLETED STUDY OR REPORT)

1. Adds to existing knowledge = adequacy
2. Active interest in study/report = pervasiveness
3. Wide application or generality = survivability

## B. INTERMEDIATE CRITERIA (REFERENT = COMPLETED TASKS AND SUBTASKS)

1. Quality = qualitative and quantitative concepts as accuracy, goodness, and worth
2. Timeliness = speed, duration, and reaction time
3. Numerosity = frequency, size, and completeness

## C. MANAGEMENT CRITERIA (SYSTEM CONCEPT IS THE REFERENT)

1. Growth Potential - Modifiability of system
2. Marketability = Number of subtasks processed in X time
3. Flexibility = Percent of total research project

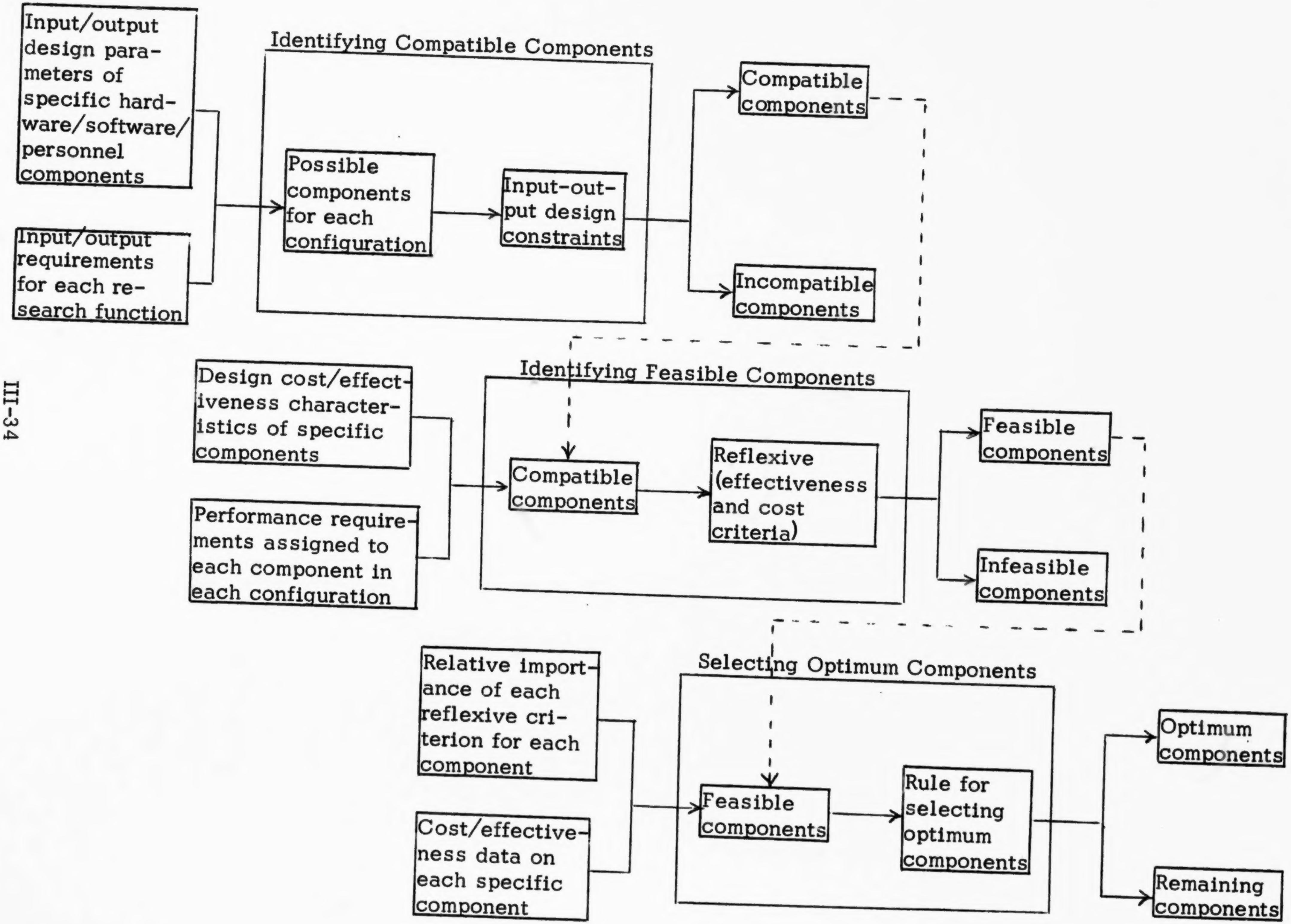
## D. PROCESS CRITERIA (SYSTEM PERFORMANCE IS THE REFERENT)

(Quality, Timeliness, and Numerosity)

## E. REFLEXIVE CRITERIA (SYSTEM COMPONENTS ARE THE REFERENT)

(Performance, Availability, Utilization)

Figure 24. Selection of System Components


Input/output design parameters of specific hardware/software/personnel components
Input/output requirements for each research function
Identifying Compatible Components
Possible components for each configuration
Input-output design constraints
Compatible components
Incompatible components
Design cost/effectiveness characteristics of specific components
Performance requirements assigned to each component in each configuration
Identifying Feasible Components
Compatible components
Reflexive (effectiveness and cost criteria)
Feasible components
Infeasible components
Relative importance of each reflexive criterion for each component
Cost/effectiveness data on each specific component
Selecting Optimum Components
Feasible components
Rule for selecting optimum components
Optimum components
Remaining components

with the general performance capabilities and limitations of various types of components. Here, we are concerned with the specific design features of particular components. Again, the question of internal compatibility (within a configuration) and external compatibility (across configurations and external to the system itself) must be resolved. Second, the magnitude of the task of screening, evaluating, and selecting components would probably tax the strength of even the most dedicated system planner. However, there are a number of aids or procedures possible. Some of these aids and procedures include: (1) identifying points of sensitivity for the various components, that is, design properties most susceptible to the required range in performance thus permitting a component to be rejected on the basis of a single factor, (2) identifying "built-in" dependencies across components, that is, interactive characteristics among functionally or structurally related components, and (3) concurrent evaluation of several components which may allow the planner to screen out a number of candidates at one time. Although there are a number of aids or procedures which may facilitate fast screening and evaluation, the basic proposition underlying the system planning guide is that all reasonable alternatives will be considered.

Prior to concluding this chapter, it may be useful to point out that the process of successively delineating the system characteristics is not completed when the particular system components have been selected. The selection of particular components now permits the system planner to describe in greater detail the specific actions to be taken by each component at each phase in planning, conducting, and documenting the research project. The design properties of the components selected influence the particular sequence and nature of activities that will be performed. The resulting detailed description of system operations provides the basis for preparing operating and maintaining documents and materials for instructing the scientists and service subsystem personnel in the operation of the various system components.

# CHAPTER IV

# ADMINISTRATIVE DESCRIPTION

# IV. Administrative Description

## A. Introduction

Two of the three major sets of activities associated with system planning and development have been covered in Chapters II and III. This chapter covers the third set of activities--management of available resources including time, money, facilities, and personnel.

During the initial phase of this project, from March 1967 to December 1967, primary reliance was placed on utilizing available written sources of information as inputs for the functional and technical aspects of system planning. In the current phase of the project, in addition to utilizing written materials, relevant data and information were acquired through on-site observations and interviews with information system planners and managers at a number of universities. Conferences were arranged with individuals actively engaged either in developing and managing specialized information systems or in planning the modernization of large university libraries. Concurrent with this shift to on-site observations and interviews, it became apparent that the managerial requirements associated with planning and developing complex specialized information systems and library modernization programs are most critical. The inherent complexity and demands of the managerial task are well known to those who have been actively involved in the evolution of either military or civilian computer-based information systems. However, surprisingly little relevant documentation on system management is available to serve as a guide for those who have had little or no experience in managing the planning, development, and operation of complex information systems. A possible explanation for the sparsity of documented experiences concerns the natural and understandable hesitancy to put into writing problems experienced, as well as findings concerning successful and unsuccessful solutions found to these problems.

The observation concerning the criticality of the managerial role in system planning and operation was further reinforced during the 1968 annual meeting of the American Society of Information Sciences (ASIS) in Columbus , Ohio. Although the formal presentations and papers had virtually nothing to say about the managerial aspects, informal discussions provided substantial information and commentary on various aspects of system management. On the basis of these two sets of experiences, the decision was made to place greater emphasis on the administrative or management aspects of system planning and development than originally had been planned.

Because of the already mentioned sparsity of relevant documentation, it was necessary to rely on three rather diverse sources of information: (1) system management-related information and suggestions offered by individuals during visits to selected universities and during the annual ASIS meeting, (2) documents discussing management aspects associated with system planning in general, and information systems planning in particular, and (3) personal experience with U.S. Naval planners and scientists during earlier research projects on computer-based command control systems.

The administrative or managerial aspects of system planning and development covered in this chapter are organized into three parts: (1) definitions of basic resource and information management functions, (2) identification of tasks involved in establishing a management organization, and (3) a comparison of management requirements during the developmental versus the operational phases of a system.

## B. System Management Functions

Figure 25 lists and broadly defines basic resource and information management functions. In this context, the resources referred to are those which have been allocated to the planning and development of the system as distinct from the system itself.[1] The resources include money, time, facilities, and personnel assigned to support the programmatic evolution of a system. The types of information required include not only information about the system planning and development resources, but also information about the resources which will logistically support the operational system. In other words, information requirements are of two sorts: information about resources used in supporting the planning and development of the system and information about resources needed to support the system when it becomes operational. The major responsibility of the system planner, functioning in the role of a manager, is to effectively match available resources or assets against system planning and development needs. To effectively accomplish this responsibility the system planner must have information about (1) the resources in terms of their availability, capabilities, limitations, locations, and numbers, (2) the system planning and development needs in terms of their functional and technical properties, temporal or sequential characteristics, and magnitude, and (3) the operational context in which the resources and needs will be matched (particularly those aspects of the context or environment which may significantly influence either the needs, the resources, or the interaction of resources and needs). One way of conceiving the management role is that the

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[1] The situation frequently exists during the life cycle of an information system in which the same resources are used to support system planning and development as are used to support a system when it is operational. The potential confusion resulting from this dual function of resources is brought up again at the end of this section.

## Figure 25. Resource and Information Management Functions

### Resource Management Functions

Allocation: Assigning and reassigning (as necessary) available resources (money, personnel, facilities, and time) to accomplish required system planning and development tasks.

Coordination: Establishing communication procedures and time schedules to insure efficient utilization of available resources.

Guidance: Preparing and disseminating instructions, policy guidance, and training materials to insure effective and directive application of resources.

### Information Management Functions

Acquisition: Includes subfunctions such as requesting, collecting, retrieving, and extracting information and data.

Analysis: Involves the evaluation of acquired data and information with respect to its relevance, completeness, and timeliness.

Process: Includes subfunctions such as compiling, formatting, indexing, disseminating, and storing relevant information and data.

system planner manages resources via management of information (96). The management of resources via management of information is performed in two different modes; i.e., a planning mode and a monitoring mode. The planning mode involves the allocation of resources through time to meet the projected system and development needs while the monitoring mode involves the supervision or checking of the actual utilization against the planned utilization of assigned resources. The planning mode matches resources to needs through a projected future time period while the monitoring mode compares present activities against projected activities.

The following discussion provides two examples of requirements associated with the system management functions. The first example deals with a resource management requirement; the second example is concerned with an information management requirement.

. One resource management characteristic common to complex information systems is the dual role assigned to some of the resources. That is, the same facilities, equipment, personnel, and money are required to support both the planning and development of a new system and the operation of a current system. The overlapping of developmental and operational phases during the programmed evolution of computer-based information systems tends to blur the already arbitrarily defined system phases (82). While the system is in an operational mode, and decisions are being made and actions are being taken to modify, replace, or add on to the present system, many of the same resources are used to support the present and future systems. This dual role can quite easily produce confusion leading to a situation in which either or both of the system activities (developmental or operational) are degraded. Gotterer (33) in his article on Organizational Philosophy and the Computer Center proposes that two distinct suborganizational units be established. According to Gotterer, one suborganizational unit within the computer center should be assigned responsibility for the operation of the current system and one suborganizational unit should be assigned responsibility for the new or improved system. Gotterer further states that the two suborganizations should be composed of individuals possessing different qualifications, interests, and traits. Personnel requirements associated with the developmental phases versus the operational phase of a computer-based information system are compared in the final section of this chapter.

. One information management characteristic associated with the long term evolution of complex information systems is the critical need for complete and accurate documentation of the decisions made during system planning and development. There is evidence to indicate that this critical need is not typically met (96). Some of the reasons for maintaining a complete record of system planning decisions, bases for decisions, and outcomes are fairly obvious. First, this type of information serves as required inputs when the system is evaluated at some later period. Second, future system planning and design can be greatly facilitated by these records. Third, the system planning and development state-of-the-art can be effectively advanced by building onto and synthesizing these documented experiences. This critical need for careful system documentation requires that a special information storage and retrieval system be designed and used during the system planning and development cycle and transferred to those who, in the future, will be given the responsibility for the next generation system.

## C. System Management Tasks

System management components include personnel and equipment which contribute to the performance of resource and information management functions, the organizational structure which reflects an allocation of management functions to different combinations of personnel and equipment components, and the communication and operational procedures which effectively link all of the components together within the organizational structure. In establishing a system management organization, there are at least five major tasks that a system manager or, in this context, a principal investigator (P.I.) needs to perform. These five tasks are covered in the following paragraphs.

An initial task required of the principal investigator in setting up a management organization is to define the types of information and resources needed to support the planning and development of a computer-based information system. Using the R-P System as an example, the information and resource requirements may be grouped into one of three categories; functional, technical, and administrative. Functional information and resource requirements encompass the full set of descriptive items covered in Chapter II, and the necessary resources needed to collect, process, and utilize this set of information items during the system planning and development phases Technical information and resource requirements include data relevant to computer-related hardware, software, and personnel items, and the necessary technical resources needed to plan, develop, and test system concepts, configurations, and components. Administrative requirements include clerical, managerial, and logistical support needed to effectively perform the resource and information management functions during both planning and monitoring activities. Information and resource support are needed to perform the resource allocation, coordination, and guidance functions; and, the acquisition, analysis, and information processing functions required of system management.

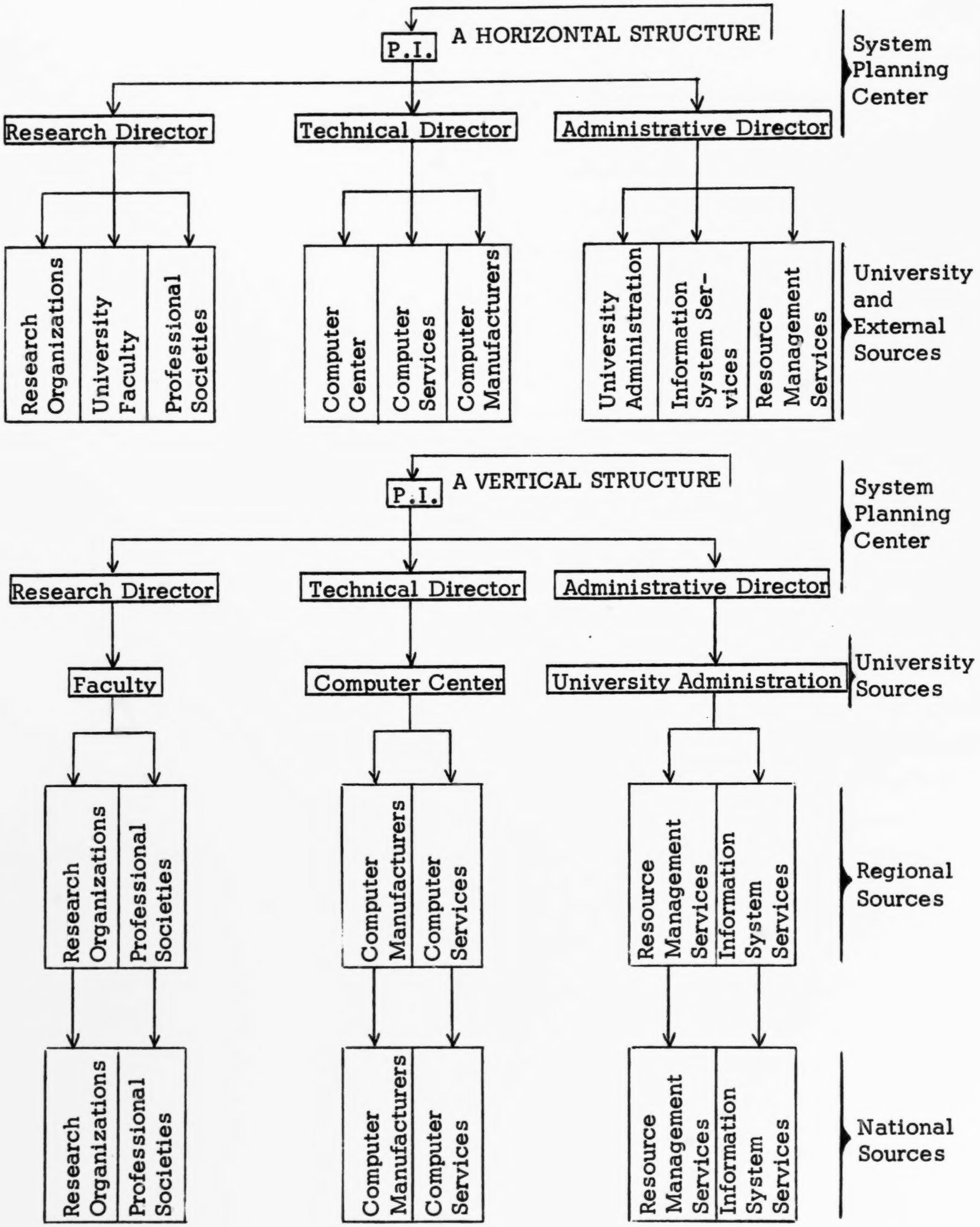
A second system management task is to identify sources for obtaining the required information and resources. The most immediate source is the staff and material assigned to the system planning and development project. The university environment provides a second major source of system information and resources. The computer center located in the university context is a rich source of technical support. The university faculty can provide functional or research-related items of information and resources and the university administration is the logical choice for administrative support. Sources, external to the university, may be local, regional, or national in character. Professional societies and research organizations are two examples of sources for functional or research-related information. Computer manufacturers and companies which commercially lease computer services - both hardware and software - represent two obvious sources for technical support. Finally, individuals and organizations knowledgeable in the areas of information system planning and resource management offer two alternative sources for meeting administrative information and resource requirements.

A third system management task involves the allocation of information and resource management functions to the assigned system planning and development staff. The system planning components of interest to this task include both the personnel and supporting equipment and materials assigned to the project. One possible procedure is to base the assignment on the nature of the information and resources required; that is, functional, technical, and administrative. According to this scheme, there would be designated a functional or research director, a technical director, and an administrative director. All of the directors would be responsive to the principal investigator. A second possible procedure is to allocate responsibility based on the functions involved; that is, resource and information management functions. One member of the staff might be responsible for one or more of the information functions - acquisition, analysis, and processing - and another member responsible for one or more of the resource management functions; that is, resource allocation, coordination, and guidance.

A fourth system management task requires the development of an organizational structure. The organizational structure reflects the above allocation of management functions to different combinations of personnel and equipment components. Figure 26 was drawn to illustrate different organizational structures. The vertical structure possesses a greater number of intermediate links. Potential advantages gained with the vertical structure include the probability of obtaining more complete information at a relatively low level of cost at each echelon. Potential disadvantages of the vertical structure include a higher probability of information distortion and slower responsiveness in meeting rapidly changing information needs. By contrast, the potential advantages of the horizontal structure include faster response time in meeting information and resource requirements - due to the fewer number of links - and higher reliability of the data obtained from the various sources.

The fifth and final system management planning task involves the formulation of communication and operational procedures which effectively link all of the system components together within the organizational structure. The established communication and operational procedures will include assignment of responsibility for administrative decision making, procedures for resolving information and resource management types of decisions, information and data needed as inputs to these decisions, administrative criteria for helping to resolve these decisions, procedures for collecting and processing the needed decision input data and information, lines of communication connecting the various components of the management organization, coordination policies and practices, and procedures for determining and reporting system planning and development status and updated plans.

Figure 26. Comparison of a Horizontal vs. a Vertical Organizational Structure


A HORIZONTAL STRUCTURE
P.I.
Research Director
Technical Director
Administrative Director
System Planning Center
Research Organizations
University Faculty
Professional Societies
Computer Center
Computer Services
Computer Manufacturers
University Administration
Information System Ser-vices
Resource Management Services
University and External Sources
A VERTICAL STRUCTURE
P.I.
Research Director
Technical Director
Administrative Director
System Planning Center
Faculty
Computer Center
University Administration
University Sources
Research Organizations
Professional Societies
Computer Manufacturers
Computer Services
Resource Management Services
Information System Services
Regional Sources
Research Organizations
Professional Societies
Computer Manufacturers
Computer Services
Resource Management Services
Information System Services
National Sources

## D. Developmental vs. Operational Phases

During visits to the various universities and at the annual ASIS meeting, a topic of common interest concerned management requirements during the system planning and development phases versus those required with an operational system. Based on (1) a range of experiences gained by those interviewed and (2) the writings of individuals who have specialized in management of systems during both the system development and operational phases, Figure 27 was prepared (8, 29, 45, 60, 70, 71, 82, 101). This figure lists some of the managerial requirements for the development and operational phases. The list is organized with respect to seven categories: primary orientation or objective, operating doctrine, organizational characteristics, resource management characteristics, information management characteristics, management/staff characteristics, and logistical characteristics. Obviously, this list reflects individual experiences with particular systems and may or may not be applicable to other than the particular situation from which they were gained. However, there seems to be a degree of intuitive reasonableness about the list sufficient to consider this as a point of departure for accumulating, under more systematic circumstances, data on managerial requirements covering a wide range of computer-based information systems.

The information contained in Figure 27 does not imply that different individuals will be required to manage the developmental and operational phases. Rather, the figure suggests that behavioral and operational goals and requirements are different. It is conceivable but unlikely that the same individual will possess the full set of qualifications and interests to satisfactorily perform the management role under both sets of circumstances.

Figure 27. Management Characteristics as a Function of System Status

| System Status<br>Categories | Developmental | Operational |
|---|---|---|
| Primary Objective | Problem solving (specific to basic purpose of system) | System viability (growth in number of users and services) |
| Operating Characteristics | 1. Mid and long range planning<br>2. Changes reactive to situational needs | 1. Monitoring ongoing operations<br>2. Programmed changes to meet planned objectives |
| Organizational Characteristics | 1. Organized around skill/knowledge requirements (subject matter, technical, administrative<br>2. Centralized decision making<br>3. Maximize informal lines of communication/coordination<br>4. Organizational changes are a function of shifting requirements (subject matter to technical to administrative) | 1. Organized around system functions (document acquisition, surrogation, etc.)<br>2. Decentralized decision making<br>3. Maximize formal lines of communication/coordination<br>4. Organizational changes are a function of growth in size and coverage |
| Resource Management Characteristics | 1. Personnel/equipment resources perform multiple roles<br>2. Decentralized control of resources<br>3. Maximize informal and inter-personal forms of coordination<br>4. Maximum use of broad and verbally delivered guidelines<br>5. Maximize re-allocation of resources to meet specific needs | 1. Personnel/equipment resources perform single roles<br>2. Centralized control of resources<br>3. Maximize formal and written forms of coordination<br>4. Maximum use of specific and written forms of guidance<br>5. Minimize the practice of reassigning resources |
| Information Management Characteristics | 1. Centralized control of resource status and system progress information<br>2. Maximize acquisition of information on nationwide, individual and organizational skills/knowledge, available services, and off the shelf items of hardware and software | 1. Decentralized control of resource status and system operating information<br>2. Maximize acquisition of information on locally available potential users of system services, sources for supporting new services, and technological state-of-the-art growth |

Figure 27 (Cont.)

| System Status<br>Categories | Developmental | Operational |
|---|---|---|
| Information Management Characteristics (cont.) | 3. Emphasize documentation of system planning decision and bases for decisions<br>4. Data used as inputs to decision making are often incomplete, general, and unreliable<br>5. System-related information tends to deteriorate rapidly in its utility | 3. Emphasize documentation of system useage<br>4. Data used as inputs to decision-making tend to be more complete, specific, and reliable<br>5. System-related information tends to deteriorate slowly in its utility |
| Management/Staff Characteristics | 1. Creative abilities<br>2. Flexible in behavior<br>3. High inter-personal skill<br>4. Problem oriented<br>5. Subject matter skills<br>6. Capability oriented<br>7. Performance sensitive | 1. Executive abilities<br>2. Organized in behavior<br>3. High product-related skill<br>4. Organizationally oriented<br>5. Managerial skills<br>6. Function oriented<br>7. Cost sensitive |
| Logistical Characteristics | 1. Must deal with unanticipated acquisition costs<br>2. Frequent non-scheduled requirements for logistical support<br>3. Developmental and make shift items<br>4. Emphasis on fabrication and testing | 1. Usually deals with known operating costs<br>2. Scheduled requirements for logistical support<br>3. Standard and off-the-shelf items<br>4. Emphasis on maintenance and operation |

The primary objective and operating characteristics shown in Figure 27 are the basic factors which dictate the nature of the other management characteristics. During the system planning and development phases, major emphasis is given to problem solving types of activity/ that is, generating alternative solutions and selecting optimum solutions which meet established functional, technical, and administrative requirements. In contrast, when the system is operational, major activities shift from problem solving to those designed to maintain the viability of the system. Furthermore, management, during the planning and developmental phases of a system, focuses on mid- and long- range planning for two reasons. First, mid- and long- range planning offer a means of providing continuous direction and guidance to system planning and development activities. Second, unforeseen obstacles and problems which occur in the present time period require management to periodically update the mid- and long-range plans. For these reasons, planning and the necessary modification of these plans is a characteristic common during system planning and development. When the system becomes operational, emphasis shifts from planning to monitoring. The greater predictability of the outcome of decisions and actions permits this shift as well as the more immediate need to be concerned with the operation and maintenance of a system in-being.

The diverse primary objectives and operating characteristics have different implications for management characteristics. The diversity of these characteristics have implications which affect the structure of the management organization, the performance of the resource and information management functions, the nature of the requirements for management and staff personnel, and the logistical support associated with either system development or system operation. Figure 27 briefly summarizes some of the implications which distinguish the developmental from the operational phases of a system.

# CHAPTER V

# SYSTEM CYCLE

# V. System Cycle

## A. Introduction

Thus far, system planning has been treated as if it were a static process made up of relatively independent types of activities. This is far from the case. In this final chapter of the report, the dynamic and interactive character of the system planning and development process is emphasized. A framework for organizing and describing both the dynamic and interactive characteristics associated with system planning and development is shown in Figure 28. The types of information required - functional, technical, and administrative are indicated in the three rows. The levels of detail, completeness, and finality of the information possible at different system planning and development stages are indicated in the five columns.[1]

Inspection of the figure indicates a twofold orientation to system planning. First, the scheme suggests that functional, technical, and administrative descriptions are developed throughout all phases with the completed descriptions staggered as shown in the figure. This concurrent descriptive effort emphasizes the interactive nature of the three types of system descriptions. That is, functional or task nature influences the technical descriptions and vice versa. The resulting system description is a composite of the influences of all three. Second, while the descriptions are interactive, separate and equal considerations of the functional, technical, and administrative aspects of a system provide the basis for developing functional or benefit criteria, technical or system effectiveness

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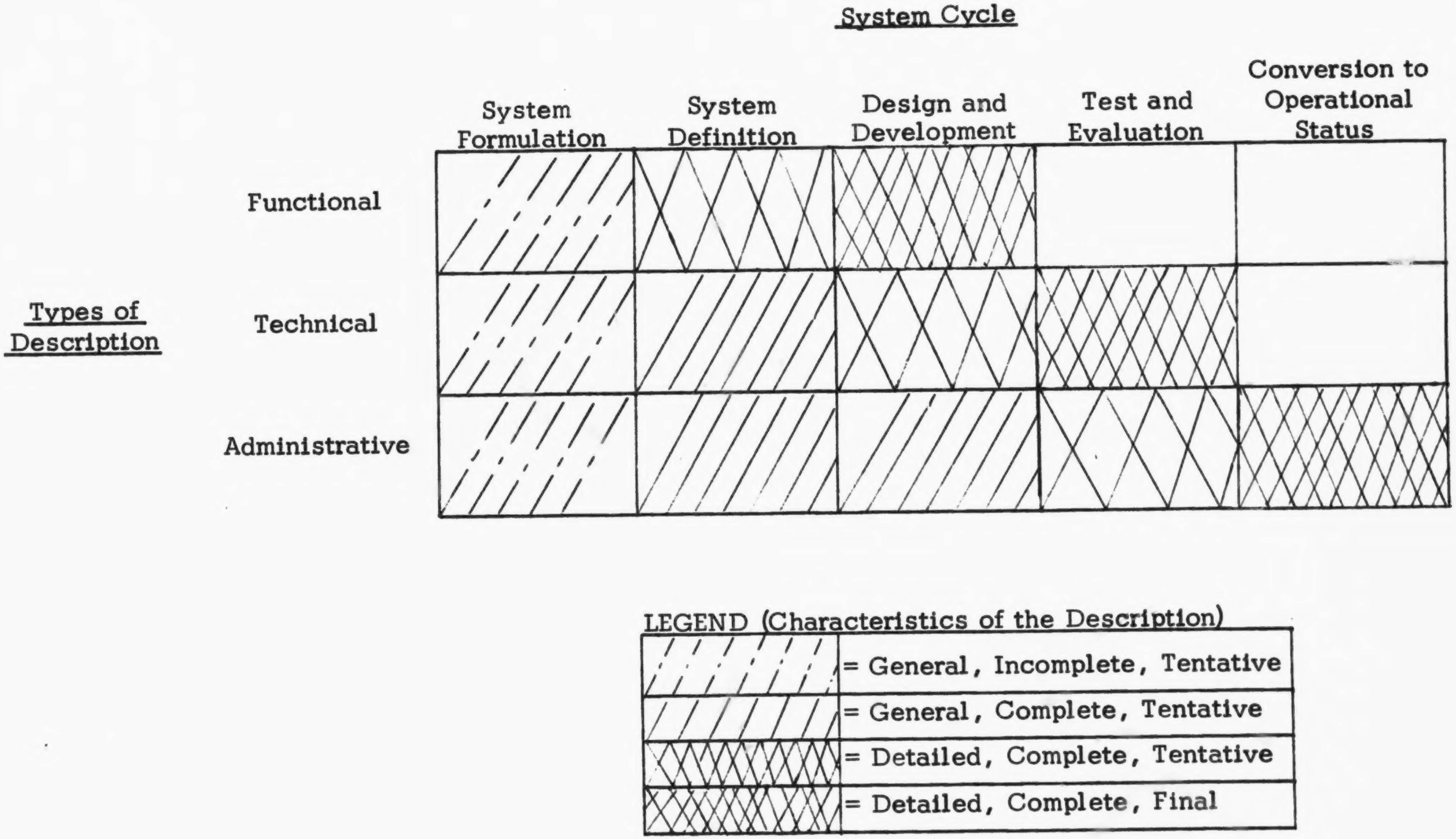
[1] The number of phases selected and the particular labels chosen to depict these phases was based on prior research experiences with the U.S. Navy in the system planning and development area and it conforms, for the most part, to their classification scheme. Various authors ( 7 , 10 , 38, 46, 82 ) have used different labels and numbers of phases but a careful review of their materials suggests that the differences are relatively minor.

Figure 28. The System Cycle


System Cycle
System Formulation
System Definition
Design and Development
Test and Evaluation
Conversion to Operational Status
Types of Description
Functional
Technical
Administrative
LEGEND (Characteristics of the Description)
= General, Incomplete, Tentative
= General, Complete, Tentative
= Detailed, Complete, Tentative
= Detailed, Complete, Final

criteria, and administrative or management criteria. All three criterion sets are needed to fully assess all aspects of computer based information systems.

With respect to the columns of the matrix in Figure 28, the column titles help to identify the predominant kinds of activities and decisions performed during each phase of the system cycle. System formulation pertains to a description of an idea or concept of a system which will perform the particular project/job. In this phase, the description is usually general, incomplete, and tentative in nature. The System Definition Phase involves the development of a complete but general and tentative description of a system. The description includes functional, technical, and administrative types of information. The Design and Development Phase represents a translation from primarily a paper and pencil exercise to the actual fabrication and installation of a prototype model. The Test and Evaluation Phase provides an opportunity to check out many of the actual performance/cost characteristics of the system against expected values. And, the Operational Conversion Phase represents a transition of the system from a prototype status to an operational status. A predominant activity during this final phase involves the programmed transfer of system management from the system designers to system operators.

With respect to the rows of the matrix in Figure 28, a functional description includes information needed about the type of project or job the system will perform, the objective of the project/job, the research or work phases of the project/job, functions or tasks to be performed during each phase, performance standards associated with each function or task, and various types of research related constraints which will affect the design and/or the operation of the system. A technical description includes information needed about the nature of the system that will perform the project, which functions will be performed by what parts of the system, what hardware/software/personnel configurations will perform required functions and specifically how each function will be performed, and what cost/effectiveness characteristics are associated with the components which make up the configurations. An administrative description includes information needed about (1) the organization which will manage the system, (2) the environment in which the project/job will be performed, (3) procedures which will be used to insure financial support of the system, and (4) the structural plans which exist for housing or containing the system and its various components.

The material presented in the remainder of this chapter is organized into two sections. The next section, Section B, identifies the scope and objective of each system cycle phase and summarizes major activities associated with each phase. Section C, the final section, describes four management aids or tools which are designed to facilitate the system planning and development process.

## B. System Phases

Figure 29 presents a summary of the major activities occurring at different phases in the development of an R-P System. Review of the figure reveals that the functional description is substantially completed by the end of the Design and Development Phase; the technical description by the end of the Test and Evaluation Phase; and, the administrative description by the end of the Operational Conversion Phase. Using Figure 29 as a reference, the following paragraphs define the objective and scope of each system phase.

The objective of the System Formulation Phase is to prepare an initial system planning proposal which includes functional, technical, and administrative information relevant to the envisioned task-oriented information system. The first column of Figure 29 lists the major activities

Figure 29. A Summary of Major Activities Occurring at Different Phases in the System Development Cycle

System Development Cycle

| | | System Formulation | System Definition | Design and Development | Test and Evaluation | Operational Conversion |
|---|---|---|---|---|---|---|
| | Functional | 1.Analysis of research projects<br>2.Delineation of project phases and tasks<br>3.Identification of user population and attitudinal/behavioral characteristics<br>4.Determination of user constraints<br>5.Definition of ultimate research project criteria<br>6.Determine university research policies | 1.Detailed description of project phases and tasks<br>2.Delineation of generic project subtasks and variations due to discipline, methods, etc.<br>3.Identification of criterion sources<br>4.Development of performance standards for project phases and tasks<br>5.Detailed description of user population | 1.Detailed description of project subtasks and identification of subtasks that cannot be structured<br>2.Development of performance standards for subtask outputs<br>3.Identification of inputs needed for each subtask<br>4.Design of pilot studies for evaluating system outputs (i.e., subtasks)during T&E phase<br>5.Develop user orientation program | | |
| ystem Description | Technical | 1.Development of system objective<br>2.Identification of required system functions<br>3.Description of technological state-of-the-art<br>4.Identify technological constraints<br>5.Perform a tentative allocation of major research functions | 1.Description of system functions<br>2.Delineation of system subfunctions<br>3.Development of system performance criteria<br>4.Generate alternative allocation of system functions and system concepts<br>5.Select optimum system concept<br>6.Generate system | 1.Description of system subfunctions<br>2.Delineation of specific system events through time<br>3.Select optimum system configurations<br>4.Develop component criteria<br>5.Tentative selection of system components<br>6.Fabrication and installation of system | 1.Design and conduct engineering tests of components and configurations<br>2.Conduct pilot studies involving performance of a sample of research subtasks<br>3.Firm up components and system procedures<br>4.Frepare operational and maintenance training | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Type of System Descript | Tec | of-the-art<br>4.Identify technological constraints<br>5.Perform a tentative allocation of major research functions<br>6.Construct a tentative system concept | 4.Generate alternative allocation of system functions and system concepts<br>5.Select optimum system concept<br>6.Generate system configurations<br>7.Identify alterantive components | tions<br>4.Develop component criteria<br>5.Tentative selection of system components<br>6.Fabrication and installation of system<br>7.Prepare software programs | of research subtasks<br>3.Firm up components and system procedures<br>4.Frepare operational and maintenance training<br>5.Determine system manning level | |
| | Administrative | 1.Analysis of administrative and contractual elements of both research and system development type of grants<br>2.Identify system buyer constraints<br>3.Identify university resources which will contribute time, facilities, personnel, and money to project<br>4.Determine university administrative policies and constraints<br>5.Identify university intent to support operational system<br>6.Establish tentative project organization | 1.Develop managerial criteria (growth potential, etc.)<br>2.Formalize the project organization and coordination procedures<br>3.Establish milestones, necessary tasks, schedule, and reporting procedures<br>4.Determine resource requirements, allocate the resources, and establish guidelines<br>5.Set up procedures and facilities for documenting decisions and decision bases<br>6.Obtain commitment of university to support system | 1.Execute monitoring of system progress, re-allocate resources, and adjust schedule as required<br>2.Maintain a running inventory on resource status and usage<br>3.Develop plan for administration and fiscal support of operational system<br>4.Maintain an ongoing documentation of system decisions and bases for decisions made<br>5.Perform necessary administrative liaison with university and external sources | 1.Prepare administrative maning and procedural documents<br>2.Prepare logistical support plan<br>3.Establish a set of policies and priorities regarding system availability and utilization practices<br>4.Organize data and information gathered by system development and prepare a report | 1.Indoctrinate technical and administrative staff re: operational maintenance and support of system<br>2.Conduct orientation sessions with system users<br>3.Supervise initial operation of system<br>4.Turn over the documented system planning records, reports, and files to operational management |

(over)

required to generate the functional, technical, and administrative inputs for inclusion in the proposal. The System Formulation Phase is initiated at that point in time when explicit and recordable actions are first taken by a university scientist(s) or university representative(s) to prepare an unsolicited proposal and is completed when the proposal is officially submitted to an agency or organization who awards system planning and development types of grants.

The twofold objective of the System Definition Phase is to (1) select and delineate an optimum system concept and (2) prepare a detailed management plan for conducting and monitoring the remaining three System Development Phases. This phase is initiated by the decision of the sponsoring agency to award a system planning grant to a particular university and is completed when a report is prepared and submitted to the sponsoring agency which satisfies the above two objectives. This phase is characterized by a large amount of system description and analysis activities. Every effort is made to secure sufficient information regarding the functional, technical, and administrative feasibility of the proposed task-oriented information system. This phase is most critical in that it represents a transition from the less costly paper and pencil type of activities to the considerably more expensive activities involving the development or acquisition of system hardware, software, and personnel components.

The System Design and Development Phase is initiated when a grant is awarded (1) to fabricate and install hardware (or utilize/lease locally available hardware) and (2) to design and develop required software. This phase is completed when a prototype model of the system exists. Parts of the system's structural and functional properties may be simulated in the prototype model rather than involving actual hardware/software items. This phase may be characterized as being highly demanding in creativity, flexibility, energy output, and record keeping.

By the end of this phase, the functional description should be essentially finalized, the system configuration(s) should be selected and alternative feasible components identified. Also there exists during this phase an intensive monitoring requirement of the progress being made; and the necessary reallocation of resources and changes in the schedule to meet unplanned for events and delays.

The objective of the Test and Evaluation Phase is to determine the engineering and participant feasibility of the prototype system model under controlled conditions. In contrast, the objective of the Operational Conversion Phase, the last phase prior to operational status of the system, is designed to check out the operational (administrative) feasibility of the system. The Test and Evaluation Phase is initiated with the design and conduct of engineering tests and feasibility testing of the scientist of participant subsystem. This phase is completed when the system components and procedures have been firmed up. The decision is often made to continue research and development activities with some parts of the system. A major decision required during this phase is to identify which research project tasks will be performed by the system under operational conditions and which project tasks will require additional planning and development efforts.

This final System Development Phase, the Operational Conversion Phase, is initiated when the decision is made to convert all or part of the prototype system into an operational system and is completed when some part of the prototype system achieves operational status. It is common with complex information systems to continue planning and development activities with those functional or technical aspects of the system for which desired types or levels of performance have not been achieved. Thus, there usually exists during the Operational Phase both planning and development activities as well as system operational activities.

## C. System Planning and Development Aids

This final section of the report describes four general types of aids or tools designed to support the system manager during the system planning and development cycle. Although the four management aids are of general utility, they are primarily applicable to different phases in the system cycle. These four types of management aids are discussed next.

### 1. System Evolution

The phrase "system evolution" as used by various writers possesses at least three different meanings. First, the replacement of obsolescent components with improved components represents one form of evolution; i.e., substituting improved hardware versions for older ones. Second, the application of the modular concept represents a second form of evolution. That is, the system is designed such that modules (components or subsystems) can be added or replaced as the nature of the requirements change or increase. The system is designed to be changed and to grow with evolving requirements. Third, within the scope of a given system, the various functions performed by the system are successively examined to see if the growing technological state-of-the-art can be used to achieve a major reallocation of responsibility from one type of component to another. For example, a system planner might allocate to hardware those functions or subfunctions which were originally performed by the human; or, allocate to software those functions initially performed by a combination of man and hardware. This concept of system evolution does not simply involve the replacing of a component by the same, but improved version of a component (i.e., hardware for hardware) but the substitution of one type of component for another type of component (i.e., hardware for man). It is the third meaning that is employed in the following discussion.

A frustration commonly encountered during the System Formulation Phase is the inability to construct a system concept which satisfactorily meets the overall desired system objective and scope. The variety and number of system related constraints uncovered during this initial planning phase are apt to significantly reduce the performance characteristics and scope of the desired system concept. Constraints originating from functional sources, technological sources,and administrative sources may likely force the system planner to select a system concept which represents a significant compromise. This type of frustration has been a common experience of individuals associated with the planning and development of complex computer-based information systems. For this reason the basic strategy of planned evolution was adopted by many information system planners.

In discussing this problem during one of the site visits, Robert Hayes, Director, Institute of Library Research, UCLA, advocated a system planning strategy which possesses considerable merit. In brief, the procedure involves the development of a system concept which completely satisfies the expressed objective and scope of the proposed system. Using this as the ultimate goal to attain, the identified constraints are arranged in order of their criticality and difficulty in overcoming. The range of constraints may include insufficient information about the functional requirements and characteristics of research project tasks and subtasks, limitations in the technological state-of-the-art, inadequate facilities to house the system, limited money or time constraints, and lack of qualified system planners and development management personnel. Given a ranking of constraints, the next step is to construct an interim system concept which can be readily realized within the known constraints. This provides a continuum consisting of the ultimate system concept at one extreme and the currently most feasible system concept at the other extreme. Within these two extremes, and using the rank ordered constraints, system concepts and associated strategies designed to successively eliminate the various constraints are laid out. That is, each succeeding system concept is, in part, designed so as to provide a means or strategy for reducing or eliminating some number of constraints. A system may go through several complete cycles (planning, development, and operation) before the ultimate stated objective is achieved.

Figure 30 shows a two cycle system evolution. The major constraint forcing the two cycle system plan stems from the inability to spell out either the processes or the requirements associated with the satisfactory performance of certain research project tasks; e.g., tasks and subtasks requiring a high degree of creative processing. As shown in this example, cycle #1 is to be used as a platform for investigating these highly internalized research activities with the goal of achieving a better understanding and ability to describe these research related behavioral processes and to uncover suitable standards for use in evaluating system outputs. It is quite possible that within the time frame of the planned system evolution, some of the constraints will not be reduced or eliminated. In which case, the system evolution will not - within the planned future - progress beyond some given system cycle.

## 2. Flow Charting

In preparing a system development plan and schedule during the System Definition Phase, it is a common practice to build the plan around the accomplishment of major system tasks or milestones. Resolution of the four classes of decisions discussed in Chapter III form

Figure 30. Reallocation of Research Functions During the Evolution of a R-P System

| Research Project Requirements | | Allocation of Primary Responsibility | |
|---|---|---|---|
| Functions | Subfunctions | System Cycle #1 | System Cycle #2 |
| Scientific | Creative (Induction) | Scientist | Joint |
| | Creative (Deduction) | Scientist | Joint |
| | Methodological | Joint | Service |
| | Subject Matter Content | Scientist | Joint |
| | Techniques | Joint | Service |
| Managerial | Clerical (Filing, Typing, Editing, Etc.) | Joint | Service |
| | Resource (Assignment, Coordination, Guidance) | Joint | Service |
| Informational | Collection/Organization | Service | Service |
| | Analysis/Evaluation | Scientist | Joint |

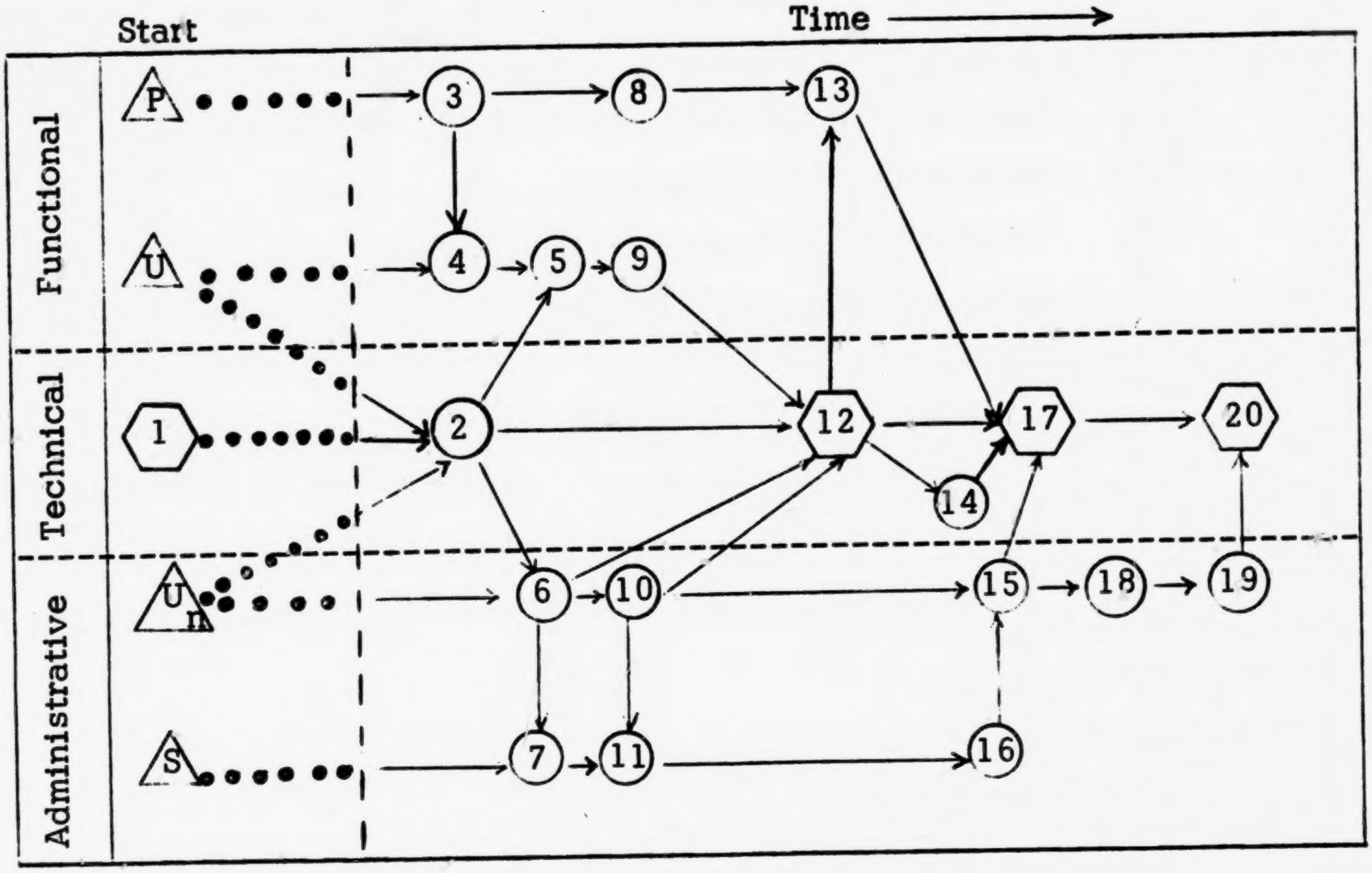
the major system planning and development milestones of this proposed system planning guide. Figure 31 provides a highly abbreviated illustration of major events and decisions involved in selecting an optimum system concept.

The octagonal shaped figures represent major system planning decision points, the circles represent events (information collection, evaluation of data and information, etc.), and the triangles represent starting points, usually possessing stored information or prior knowledge on relevant matters. The horizontal lengths of the arrows connecting the numbered figures represent the projected time needed to accomplish the task/activity from which the arrow originates. Direction of the arrows represents output from and input to different activities and decisions. More detailed descriptions of various graphic techniques useful in system planning are found in the attached bibliography. Some relevant references are 38, 55, 71, 98.

### 3. System Description

One of the problems which typically becomes apparent during the Design and Development Phase concerns the effective use of the functional information generated during the earlier system planning phases. The form and characteristics of the functional description are often not amenable as inputs to the technical design of the system. Although the importance of the functional description may be apparent to system designers, the problem is how to use the information as inputs in designing the technical aspects of the system. For example, while there exists a growing body of information and data on the research-related behaviors of scientists (26, 34, 35, 54, 75), it is difficult to see, except at a fairly general level of guidance, specifically how the documented behavioral characteristics of scientists can be used as inputs

Figure 31. Flow Charting Major Events and Decisions in Selecting an Optimum System Concept



| | |
|---|---|
| 1 | Research functions have already been allocated. |
| P | Descriptions of research project phases, tasks, subtasks are available. |
| U | Information exists on research related attitudes and activities of scientists. |
| Un | Information exists on university policies, constraints, and intents. |
| S | Information exists on sponsor constraints and guidelines. |
| ② | Scientists, technical personnel, and administrative personnel contribute to the development of alternative system concepts. |
| ③ | Identification of sources for criterion data and information. |
| ④ | Scientists provide project personnel with criterion source information. |
| ⑤ | Information on responses of scientists to proposed system concepts. |
| ⑥ | University administration reviews proposed system concepts. |
| ⑦ | Sponsor reviews proposed system concepts. |
| ⑧ | Collection and processing of criterion data and information. |

Figure 31 (Cont.)

⑨ Scientists constraints relevant to proposed system concepts.

⑩ University based interface constraints.

⑪ Sponsor provides guidance regarding alternative system concepts.

12 Identification of compatible system concepts.

⑬ Development of performance standards for project subtasks.

⑭ Projections made on costs and capabilities of alternative system concepts.

⑮ University provides criterion values for cost/benefit measures.

⑯ Sponsor provides guidance in terms of cost/benefit considerations.

17 Identifying feasible system alternatives.

⑱ Establishing relative importance to various managerial cost/benefit criteria.

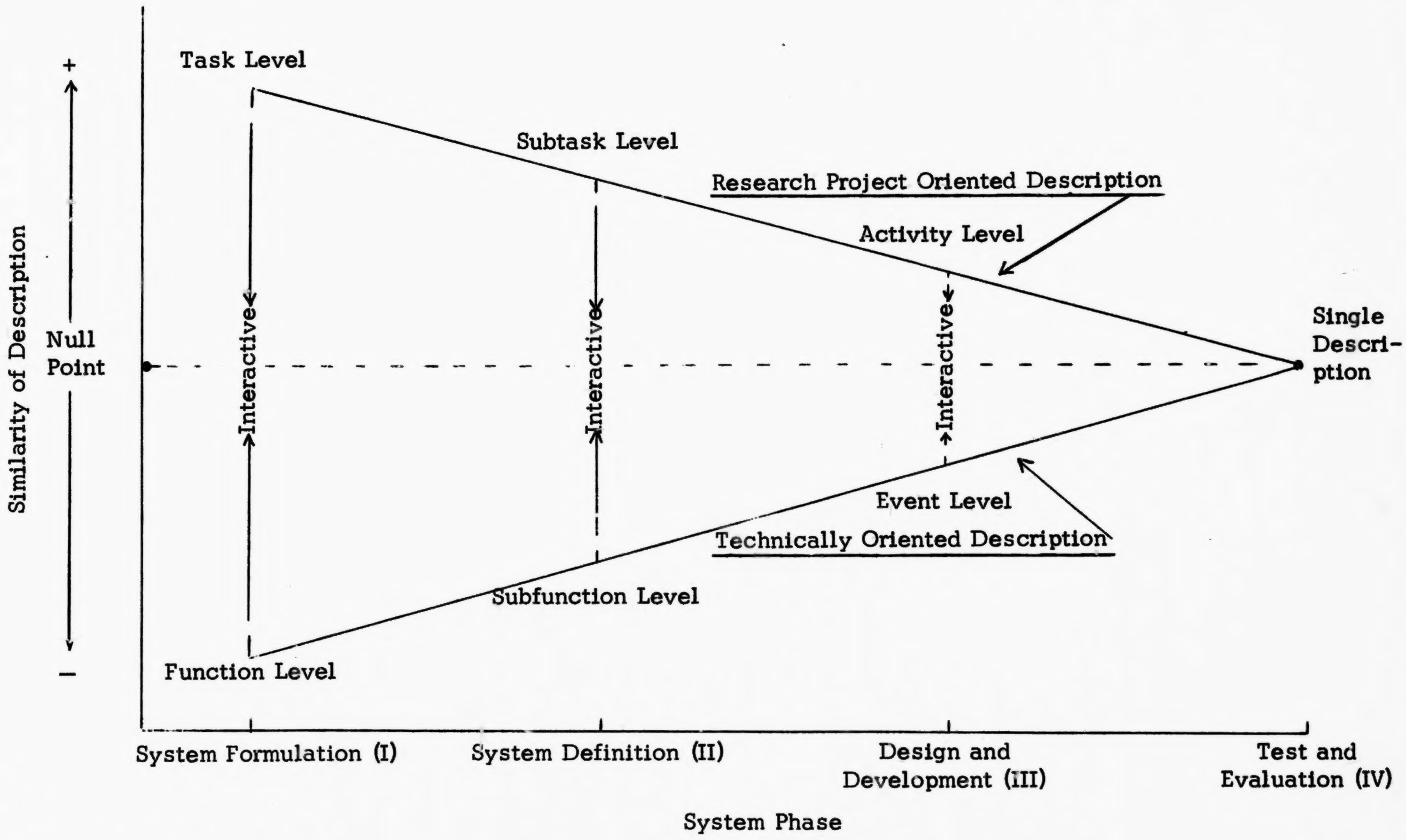
⑲ Development of a rule for combining the weighted managerial criteria.

20 Selection of an optimum system concept.

in designing or fabricating software programs or terminals which interface with the scientists.

To illustrate a possible procedure for handling this problem, Figure 32 was prepared. The figure is intended to depict the relationship of research project (or research-related activities) to system-oriented (technical) descriptions as a function of system phase. The figure illustrates three aspects of a procedure involved in blending functional and technical descriptions. First, the dissimilarity of the descriptions is greatest during the initial System Formulation Phase, becoming progressively more similar until a single system description suffices in the Test and Evaluation Phase. During the initial System Formulation Phase, the list of research project tasks imply operational or behavioral activities or outputs while the list of functions (scientific, management, and informational) imply capabilities or processes. The system functions represent broad level inferences made about skills and knowledge requirements (labelled as functional requirements) covering the range of project tasks. Each research task may require more than one class of skills and knowledge which are differentially weighted in terms of relative importance or demands. At the subtask level, the level of the description is such that it is easier to intellectually group the nature of the processes or capabilities required to achieve the subtask output or activities. Likewise, the system labels attached to the subfunctions (e.g., clerical and resource management) are such as to imply - at a more operational level - the activities involved. As the level of description is more refined to the activity level/event level the obvious similarity of the two classes of description is apparent since both the functional and the technical aspects are mutually influencing the descriptive properties of the other. This brings up the second point. The arrows shown in Figure 32 which connect the

Figure 32. Relationship of Research Project to Technically Oriented Descriptions as a Function of System Phase


Task Level
Subtask Level
Research Project Oriented Description
Activity Level
Single Description
Interactive
Interactive
Interactive
Event Level
Technically Oriented Description
Subfunction Level
Function Level
Similarity of Description
+
Null Point
−
System Formulation (I)
System Definition (II)
Design and Development (III)
Test and Evaluation (IV)
System Phase

research project and technical descriptions at each system phase indicate that the respective descriptions are mutually influenced by consideration of the other type of description. The descriptive process is interactive. Thus, at the activity/event level, both descriptions are worded in similar terminology, and they merge at the Test and Evaluation Phase into a simple system description. Third, it is quite difficult to separate the functional from the technical (or system-dependent) facets of an operational system. The activities associated with the performance of a job or project and the outputs are influenced by the system characteristics. The deceptionally easy appearing task of isolating technical and functional system inputs has produced its share of problems when working with current operational systems. The imposition of administrative procedures on top of the integrated functional and of technical system description further complicates the task of deciding - when analyzing an operational system - what system inputs, processes, and outputs are attributable to administrative, technical, and functional considerations.

### 4. Test and Evaluation Alternatives

The problem of information system testing and evaluation has received a lot of attention and mixed reactions during the past 8-10 years. A number of excellent articles and books have been written on various aspects of information system testing and evaluation. A sample of the relevant material reviewed include 9, 11, 14, 16, 38, 41, 46, 56, 58, 59, 81, 82, 87. Since many of the critical problem issues regarding the evaluation of information systems have already been raised and discussed in the preceding chapters, no attempt will be made to re-introduce these issues; rather, it would be appropriate in this section to point out characteristics common to information system testing and evaluation. Below are briefly discussed six of the phenomena found to exist with information system testing and evaluation.

- Testing and evaluation activities are not restricted to the so-called Test and Evaluation Phase. System testing and evaluation is a continuous process and is performed throughout the life cycle of an information system. Because there is a major allocation of resources to test and evaluation activities subsequent to the installation of a prototype model, it has become conventional to label this phase as the Test and Evaluation Phase.

- Testing and evaluation may be conducted for one of three broad purposes. These broad test objective areas include (1) exploratory and theoretical purposes (e.g., development and checkout of techniques), (2) experimental and applied research purposes (e.g., demonstrating the practical application of an information processing procedure), and (3) implementation and operational purposes (e.g., to demonstrate system performance).

- Test and evaluation methods and settings encompass a wide range of analytic and empirical techniques. Some of the major techniques include mathematical modeling and model exercising, functional simulation, non-mathematical analysis (for example, personnel judgment), engineering modeling, field testing, controlled observation under simulated or sampled operational conditions, use of questionnaires and interview techniques, and controlled experiments.

- Test and evaluation activities span the system hierarchy. That is, they include component testing, system configuration testing, whole system testing, and multi-system testing.

- There are three classes of testing and evaluation which correspond to the types of system descriptions; i.e., participant-oriented or functional evaluation of the system, engineering-oriented or technical evaluation of the system, and management-oriented or administrative evaluation. For each class, there are appropriate criteria, criterion measures, questions to be answered, and methods for obtaining answers to these questions.

. Testing and evaluation activities can be cross-sectional in nature or longitudinal. Cross-sectional evaluations are usually short in duration and include a representative sample of system components or activities. Longitudinal evaluations are designed for long duration runs involving continuous or intermittent collections of data on the performance of components, configurations, or the entire system.

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# APPENDIX A

# RESEARCH PROJECT MODEL

# APPENDIX A

# RESEARCH PROJECT MODEL

## Introduction

The first section of this appendix presents two basic variations of a research project model: a model based on an experimental or statistical approach and a model based on a controlled investigation approach. The basic research project model is organized in terms of phases, tasks, and subtasks. The tasks within each phase represent successive milestones which must be met to complete the research phase. The subtasks are specific activities with definable outputs which are required during the conduct of each task. The six general phases include: I. Proposal Preparation; II. General Planning (Scheduling Personnel Assignments, Facilities); III. Detailed Planning (Hypothesis Development, Sampling, Criterion Development, etc.); IV. Data Collection; V. Analysis and Interpretation of Data; and VI. Report Preparation. The experimental/statistical and controlled investigation models vary in their Detailed Planning and Data Collection Phase but are identical for Phases I, II, V, and VI.

In the interim report, five factors influencing the type of subtasks required during the conduct of Phases III and IV of a research project were listed. These included: discipline or subject matter, research objectives, research methods or settings, scale of measurement, and types of explanation. The first three factors listed were considered to have the most impact in shaping the characteristics of the research project. As a preliminary check, a representative sample of journal articles from different disciplines were reviewed. The second section of this appendix presents a classification of the findings from 60 journal articles covering research objective, research method, and subject area/discipline.

# Part I. Research Project Model

## Phase I - Proposal Preparation

### Task I-1. Development of Informal Proposal

Output: Preparation of an informal paper containing identification of the problem, preliminary hypotheses, alternative approaches, historical information, rationale, and significance of the problem.

Subtasks:

- Identification of problem (content, methodology, technique).
- Acquisition, compilation, organization of available topic related information.
- Review, screening, and extraction/tagging of relevant chunks of information.
- Analysis of chunks of information.
- Formulation of hypotheses.
- Checking of hypotheses for consistency, meaningfulness and originality against available chunks of information.
- Developing rationale to support hypotheses.
- Formulating/checking some broad alternative approaches/methods for testing hypotheses.
- Organizing relevant historical background.
- Drafting of preliminary (pre) proposal.
- Typing of proposal.
- Editing of proposal.

### Task I-2. Determination of Support Sources, Feasibility, and Requirements

Output: Determination of potential sources of support, cost/time/scope constraints, and proposal requirements.

Subtasks:

- Identification of potential sponsors - information on kinds of research being supported and what work is being carried on currently in problem area of interest.
- Determination of best match between potential sponsors and own research interests.
- Identification of steps and procedures recommended by sponsoring agencies for submitting and informally discussing proposal ideas.
- Revision if necessary of pre-proposal based on results of above subtasks.
- Send/carry pre-proposal to sponsoring agency and discuss proposal ideas with sponsors.
- Determine the amount of money that is available for research of the proposed type.
- Identify the sponsors time constraints (six months, one year, etc.).
- Identify formatting and technical proposal requirements and procedures for submission.

### Task I-3. Modification/Elaboration/Revision of Pre-Proposal

Output: Preparation of a formal proposal based on guidelines obtained from Tasks 1 and 2.

Subtasks:

- Spell out, in more detail, the alternative approaches identified in Task I-1. Include discussion of pros and cons for each alternative approach (rationale).
- Search, in more depth, the literature in the selected topic area with particular emphasis on finding support for or identifying positions which are discrepant with the one proposed.
- Describe in greater detail the hypotheses and their underlying rationale.
- Draft final proposal.
- Type final proposal.
- Edit final proposal.
- Submit final proposal to selected sponsoring agency.

## Phase II - General Planning

### Task II-1. Development of a General Plan/Schedule for Conducting the Proposed Effort

Output: Identification and description of major resources and development of a general task schedule for conducting the proposed research.

Subtasks:

- Obtain information on what personnel are available for what lengths of time. Include training, experience, capabilities, salaries, location (on/off campus), etc.
- If consulting help is required, identify and contact possible candidates.
- Determine what facilities are available, where they are located, how well they meet the project requirements, how much they cost and for how long they are available.
- Identify information services that are available and the lag time and cost characteristics of these services.
- Develop task schedule based on estimates of how long and what level of effort is required to complete each proposed task.
- Match personnel capabilities with task requirements and assign personnel to perform tasks.
- Identify tentative end products for each task.
- Prepare a general plan for making use of available facilities and information services.
- Type task schedule, personnel assignments, and plan for use of facilities and services.
- Submit typed material to university administration, support services, colleagues, etc.

### Task II-2. Modification/Addition/Revision of Plan

Output: Final plan for schedule of tasks, level of effort, personnel assigned, and facilities and services to be used.

Subtasks:

- Discuss plan with university administration, support services (facilities, etc.), and colleagues to determine changes required, etc.
- Based on feedback from discussions during Subtask 1 above, modify schedule, facilities to be used, etc.
- Type up final general plan.
- Submit general plan to university administration, to support services directly involved, and to project personnel.

## Phase III - Detailed Planning (Experimental and Statistical Variations)

### Task III-1. Identification of Relevant Variables

Output: Detailed description of the variables that are related to the proposed problem area.

Subtasks:

- Review literature for discussions of relevant variables and their characteristics - how they have been controlled, manipulated, measured, etc.
- Discussions with colleagues working on similar or associated problem areas.
- Make a list of relevant variables identified from literature, from colleagues, from own experience.
- Determine the underlying characteristics of each variable.
- Determine measurement sensitivity of each variable (type of scale - ordinal, interval, etc.).
- Identify manipulation and control characteristics associated with each variable listed (methods and results sections of research conducted in the area of interest).

### Task III-2. Development of Detailed Hypotheses

Output: Specifically stated hypothesis which identify and relate independent and dependent variables.

Subtasks:

- Delineation of subtasks covering Tasks III-2 through III-8 is a function of the specific research objective, discipline, and methodology involved in the study.

### Task III-3. Classification of Relevant Variables

Output: A list of relevant variables classified with respect to their role in the study (independent, dependent, contextual).

### Task III-4. Selection of a Study Setting

Output: A description (in detail) of selected study setting and the rationale for its selection.

### Task III-5. Development of Experimental/Statistical Design*

Output: An experimental design including a description of (1) how the independent variables will be manipulated (and compared) or their actions recorded and (2) what variables will be controlled and the method selected for controlling.

### Task III-6. Selection of Sampling Unit

Output: Selected sample with (1) description of characteristics and (2) plan for how subjects or materials are assigned to experimental conditions.

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[*] The primary distinction between the experimental and statistical design is that in the statistical approach, levels of a variable are sampled rather than manipulated.

### Task III-7. Criteria Selection/Development

Output: A set of criteria and criterion measures to be used in the project.

### Task III-8. Design, Development and Checkout of Apparatus, and Measurement and Recording Techniques

Output: Apparatus and initially delineated procedures.

### Task III-9. Development and Pretesting of Data Collection Procedures

Output: Final design of the controlled investigation, data collection procedures, and apparatus.

Subtasks:

- Set up experimental or controlled investigation design and apparatus.
- Select a few subjects or materials - those that will be representative in the experiment or controlled investigation.
- Run each experimental condition or make necessary observations.
- Check for: ease of administration, precision of observation and measurement techniques, clarity of instructions, etc.

## Phase IV - Data Collection (Experimental and Statistical Variations)

### Task IV-1. Preparation of Sampling Unit for Study

Output: Subjects/units ready to begin the experiment.

Subtasks:

- Instructions to subjects, preparation of materials.
- Do some practice runs, check adequacy of preparation.
- Allow subjects to adapt to test environment, etc.
- Specific actions taken depend on -
  - The nature of the sampling unit (living, non-living, etc.).
  - The experimental conditions.
  - The nature of the study setting.
  - The method of observation/recording.

### Task IV-2. Quality Control

Output: Detection of errors or deviation from plan.

Subtasks:

- Periodically check to see if apparatus is working properly.
- Check on behavior of subjects.
- See that data are being recorded accurately.
- Check measurement techniques to see if required level of precision is being achieved.

### Task IV-3. Compiling and Summarizing Data

Output: Data in summary form.

Subtasks:

- Need to know: objectives, hypotheses, experimental conditions in order to spell out the subtasks required in Task IV-3.

## Phase III - Detailed Planning (Controlled Investigation/Variation)

### Task III-1. Identification of Relevant Variables

Output: Detailed description of variables that are related to the proposed problem area.

Subtasks:

- Review literature for discussions of relevant variables and their characteristics (e.g., how they have been controlled, manipulated, measured, etc.).
- Discussions with colleagues working on similar or associated problem areas.
- Make a list of relevant variables identified from literature, from colleagues, from own experience, previous research, etc.
- Identify characteristics of the relevant variables - range, stability, etc.

### Task III-2. Development of Detailed Hypotheses

Output: Specifically stated hypotheses which identify (and relate) the variables to be investigated. In a controlled investigation, the hypotheses is usually derived from one of two major sources: (1) a model and (2) previous findings.

### Task III-3. Classification of Relevant Variables

Output: A list of relevant variables classified with respect to their role in the study (which variables will be controlled, which will be measured).

### Task III-4. Selection of Study Setting

Output: A description of selected study setting and rationale for its selection.

Subtasks:

- List out the relative advantages and disadvantages of various environments in which to conduct the research project (lab, field, etc.).

- Decisions should be made based on: (a) nature of behaviors of interest (complex - simple, macro - micro, etc.) and (b) study objectives (look at one or several variables simultaneously).

### Task III-5. Development of Controlled Investigation Design

Output: A research design including descriptions of measurement and control procedures.

Subtasks:

- Determination of control procedures.
- Set up schedule for taking measurements, e.g., time sampling.
- Set up schedule for systematically varying factors of interest.

### Task III-6. Selection of Sampling Unit

Output: Description of sampling procedure and characteristics of the sample.

Subtasks:

- Select samples.
- Prepare samples for use in the study.

### Task III-7. Design Development and Checkout of Apparatus and Measurement and Recording Techniques

Output: Apparatus and measurement procedures.

Subtasks:

- Consideration of alternative measurement techniques. The advantages and disadvantages of the application of existing measurement techniques to the factors of interest in the study.

- Selection/development of measurement instrumentation.
- Determination of criterion/dependent variables.

### Task III-8. Pretesting of Proposed Instrumentation and Measurement Techniques

Output: Final instrumentation and measurement package.

Subtasks:

- Run some pretest trials using proposed instrumentation.
- Pretest measurement techniques on small sample.

## Phase IV - Data Collection (Controlled Investigation Variation)

### Task IV-1. Application of Measurement Techniques to Sample

Output: Measures of factors of interest.

Subtasks:

- Prepare sample.
- Take measurements according to measurement schedule.
- Record and summarize measurement data.

### Task IV-2. Quality Control

Output: Detection of errors and deviation from plan.

Subtasks:

- Periodically check on instrumentation to insure its proper functioning.
- Check to insure that data are being recorded accurately.
- Check measurement techniques to see if required level of precision is being achieved.

## Phase V - Analysis and Interpretation of Data

### Task V-1. Descriptive or Inferrential Analysis of the Data

Output: Experimental status.

Subtasks:

- Subtasks are based on following considerations: study objectives, hypotheses, nature of variables, experimental design, methods, criterion measurement sensitivity, etc.

### Task V-2. Interpretation of Results

Output: A discussion of how results relate to other work in the field and what the implications are - both as contributors to the body of scientific knowledge and for practical application (if any).

Subtasks:

- Review literature and extract information (results) which are similar/different from results obtained in present study.
- Compare results obtained with previous results and develop integrated picture.
- Interpret results with respect to study objectives and hypotheses.
- Determine what practical or potential practical application results might have.

## Phase VI - Report Preparation

### Task VI-1. Prepare Report Draft

Output: Report draft.

Subtasks:

- Organize collected materials/information into sections (e.g., Introduction, Methods, Results, Discussion, Recommendations, and Conclusions).
- Check formatting requirements (journal, technical report, etc.).
- Type preliminary draft.
- Review and editing.
- Type final draft.
- Quality control the completed draft.

Task VI-2. Submit Draft Report to Sponsors or Article to Journal Editors

Output: Modifications and additions suggested by sponsors or editors.

Subtasks:

- Submit report for review by sponsors or journal references.
- Discuss results with sponsors.

Task VI-3. Preparation and Submission of Final Report (may be in form of journal article, monograph, technical report, etc.)

Output: Final report.

Subtasks:

- Modify/rewrite draft report based on recommendations from sponsors or journal editors.
- Final review and editing.
- Final typing.
- Final quality control of report.
- Submit approved report for publication and mass dissemination.

## Part II. Classification of Research Studies

Three major factors which influence the conduct of a research project are (1) the research objectives, (2) the research method, and (3) the subject area or discipline. For purposes of classifying the research literature reviewed, seven general types of objectives were identified.

- To demonstrate the existence of a phenomenon (e.g., color vision).
- To demonstrate the existence of a cause-effect relationship between two or more variables. To show that B is a direct result of A.
- To demonstrate a functional dependence between two or more variable magnitudes or values.
- To generate hypothesis concerning the characteristics of the phenomenon under investigation. Literature reviews, historical studies, and observational studies in "real world" contexts may be used to gain insights into the nature of a phenomenon.
- To develop and evaluate a technique or method. The technique may be concerned with controlling a variable, applying a set of measurements or observing, and recording experimental data.
- To adequately and accurately describe a phenomenon. An example of this type of research would be an ethnography.
- To test the validity and/or reliability of a model which has been constructed to represent some process, function, or behavior. The accomplishment of this type of objective usually involves the application of analytic techniques and mathematical formulas.

The four research method categories include: the experimental approach, the statistical approach, the controlled investigation, and the analytic approach. The five discipline/content classifications selected are Physics and Physical Sciences; Chemistry; Biology and Physiology; Experimental and Applied Psychology; and Social Psychology, Sociology and Anthropology. These areas were used as a basis for sampling the research articles to be reviewed. The number of articles reviewed and categorized per area ranged from 10 to 15. Sixty articles comprised the entire sample.

Tables 1 and 2 show the distribution research articles by -

- Objectives and disciplines.
- Research method and discipline.
- Research method and objective.

In the objective by discipline distribution, it can be seen that the studies reviewed in the Physics/Physical Sciences and Chemistry content areas tend to follow the same pattern; they are more evenly distributed across objective classes than the other three content areas. The Biological, Behavioral, and Social Sciences appear to concentrate most of their efforts in two objective classes: (1) the demonstration of a cause-effect relationship and (2) the demonstration of functional relationship. For the research method by content area classification the results in Table 1 show that (1) controlled investigation is the principle method for Physics/Physical Sciences and Chemistry, (2) experimental manipulation is the main method for Biology, Physiology, and Experimental and Applied Psychology, and (3) statistical manipulation and controlled investigation are the methods most used by the social scientists included in the sample. Table 2 shows a high relationship (1) between the cause-effect objective class and the experimental manipulation method and (2) between the evaluation of a technique objective class and the controlled investigation method.

Table 1. Distribution of Articles by (1) Objectives and Discipline and (2) by Research Method and Discipline*

| Objectives | Physics/ Physical Science | Chemistry | Biology/ Physiology | Experimental/ Applied Psychology | Social Psychology/ Sociology |
|---|---|---|---|---|---|
| Demonstrate a phenomenon | 4 | 3 | | 1 | |
| Cause-effect | 4 | 4 | 6 | 6 | 1 |
| Functional relationships | | | 1 | 5 | 7 |
| Generate hypotheses | | | | 1 | |
| Evaluation of technique/ equipment | 2 | 2 | 2 | 2 | 3 |
| Description | 1 | 1 | | | 1 |
| Model test | 3 | 2 | | | |
| Research Method | | | | | |
| Experimental | 3 | 3 | 7 | 13 | 1 |
| Statistical | | 1 | 1 | 1 | 5 |
| Controlled investigation | 6 | 8 | 1 | 1 | 6 |
| Analytic | 3 | | | | |

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* The number in each cell represents the number of journal articles which match the particular classifications by (1) objective and discipline and by (2) method and discipline. Two of the articles had more than one objective; consequently, the total number in the objective by discipline category is 62 rather than 60.

Table 2. Distribution of Articles by Method and Objective

| Research Method | Objectives |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  | Demonstration Phenomenon | Cause Effect | Relational | Generate Hypothesis | Evaluation of Technique | Description | Model Test |
| Experimental | 3 | 16 | 4 | 1 | 3 | 1 |  |
| Statistical |  | 2 | 6 |  |  |  |  |
| Controlled Investigation | 3 | 4 | 4 |  | 8 | 2 | 2 |
| Analytic | 2 | 1 |  |  |  |  |  |

# APPENDIX B

# INFORMATION-BASED INFORMATION SYSTEMS

# APPENDIX B

# INFORMATION-BASED INFORMATION SYSTEMS

## I. Introduction

### Purpose

As part of the project effort, a detailed description was developed of the planning, development, and operation of five campus-based information systems. The original purpose for obtaining descriptions of these five selected systems was four-fold:

- To provide a check of the information system planning guide presented in the interim report.*
- To expand the user model to include industrial as well as academic research scientists.
- To determine the information related requirements of scientists (academic and industrial) throughout the phases of a research project.
- To expand the information system service model.

Two major problems were encountered in attempting to achieve these objectives. The first problem was concerned with obtaining an adequate check of the system planning guide. In all five cases, none of the system planning processes/decisions had been documented. Additionally, it was apparent that the planning and development of these systems was primarily guided by constraints rather than by the evaluation of alternative courses of action. The second problem was concerned with obtaining information about the user population and their requirements. Because of the proprietary nature of their research work, the detailed study of the industrial scientists as system users was infeasible.

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* Whittenburg, J. A. & Schumacher, Anne W. An information system planning guide: Preliminary development and checkout. Alexandria, Virginia: Whittenburg, Vaughan Associates, Inc., February 1968.

## System Descriptions

The five systems and the individuals responsible for their planning, development, and operation are presented below. Two of these systems, SPIRES and BIS, serve the academic community; two, KAS and PENNTAP, serve the industrial community; and one, RICE, serves both the academic and the industrial communities.

- The Regional Information and Communication Exchange (RICE) is located at Rice University in Houston, Texas. Discussions concerning the planning and developing of RICE were held with Mr. Frederick Ruecking.
- The Knowledge Availability System Center (KAS) is located at the University of Pittsburgh. Discussions concerning the planning, development, and operation of KAS were conducted with Mr. Allen Kent, Mr. Edmond Howie, and Mrs. Elizabeth Hartner.
- PENNTAP, the State Technical Services Center, is located at Pennsylvania State University. Discussions were held with Mr. Anthony Vennett.
- The Stanford Physics Information Retrieval System (SPIRES) is located at Stanford University. Discussions were held with Dr. Edwin Parker and members of his staff.
- The Brain Information Center (BIS) is located at the University of California at Los Angeles. Discussions were held with Dr. Robert Hayes and Dr. Peter Amacher.

A detailed description of each of these systems is presented in Part II of this appendix.

## Classification of Systems

One way in which information systems can be categorized is in terms of their stated objectives. Five general classes of objectives have been identified:

(1) To provide the user with information in the various forms in which it is available to the system in response to specific (user originated) demands.

(2) To provide the user with information in the form desired in response to a specific (user originated) demand. In this case the form in which the information is presented is not restricted to what is available in the system. Thus, the system may create special summaries, review articles, etc. tailored to individual requirements.

(3) To provide the user on a regular schedule with a listing of titles and/or abstracts which represent the materials currently acquired by the system. One example of this type of system is the Clearinghouse for Scientific and Technical Information.

(4) To provide the user on a regular schedule with a selective listing of titles and/or abstracts of the materials currently acquired by the system. This selective listing is usually based on an interest profile submitted by the user.

(5) To perform those tasks with, or in support of, the user which are aimed at producing a product (e.g., technical research report). These tasks are not limited to the provision of information.

Of the five systems characterized, two (SPIRES and RICE) are representative of the first class of objectives; two (BIS and PENNTAP) of the second class of objectives; and one (KAS) of the fourth class of objectives.

## II. System Descriptions

### Regional Information and Communication Exchange
### (RICE)

### History/Development of System

#### Purpose

To centralize the bibliographic resources of the Texas gulf region and make this resource base available to colleges, universities, and industries in the area.

#### Background

- In October of 1964 work was begun to mechanize the interlibrary loan system at Rice University.
- In 1965 the Rice library was offered access to an IBM 7040 computer (the load on the computer was small and there was a requirement to make full use of available machine time).
- In 1965 the university received a systems grant from the National Science Foundation. This grant is still being continued; $13,000 was allocated to the library to study how the library could augment the research of the faculty. As part of this study a classification of subject materials (places, people, dates, meetings, essays, etc.) was developed for a faculty member who was writing a definitive bibliography on Thomas Mann. Twenty-six thousand dollars was allocated to the library to evaluate the effectiveness of providing a SDI service to chemistry faculty using Chemical Abstract tapes.
- In 1965 information became available on the teletypewriter link that had been set up between Columbia, Harvard, and Yale. This kind of system was of great interest.

- In 1966 (February) Project MARC was initiated. Rice University was selected as one of the original MARC participants.

- In May of 1966 the concept of the Regional Information and Communications Exchange (RICE) emerged. This was in part a result of an attempt to move the Technical Information Center from the University of Houston to Rice University.

  - A grant was received in June 1967 from the Department of Commerce to provide information to industries in the region.
  - A special purpose grant was received from the Office of Education to build up the resource base.
  - A special merit grant was obtained to include part of Louisiana in the network.
  - In May 1968 a grant was received from NSF to complete and automate the RICE network.

System Development

- The RICE network is to include 18 colleges and universities in the Gulf Region. This concept evolved because it was determined from an examination of the large university library budgets that no one library could afford to acquire all of the required materials.

- The colleges and universities to be included in the network are:

  - University of Houston
  - Rice University
  - McNeese State College
  - Lamar State College of Technology
  - Del Mar State College of Technology
  - Stephen F. Austin State College
  - Sam Houston State College
  - University of St. Thomas
  - Houston Baptist College
  - Alvin Junior College
  - Victoria Junior College
  - Texas A & I University
  - Loredo Junior College

- Texas Southern College
- Lee College
- Institute Tecnologico (Mexico)
- Wharton Junior College

- The bibliographic information on the materials held in these collections will be included in a central computer file at Rice University.

- Information (resources) in the network will be made available to colleges, universities, and industries in the area.

- At the present time five colleges are actually participating, the remaining 13 are in the process of making formal commitments.

- The only function currently being performed by the computer is accounting and billing.

- Transferring of bibliographic information to tape was initiated in May 1968.

- Requirements for the system include:
  - Fast communication between members of network.
  - Identification of what materials are available where.

Marketing

Major problem is how to inform small industries of the capabilities of the RICE System and how to make use of these capabilities.

Methods of marketing RICE -

- 3,000 newsletters at regular intervals - industries.
- Newspaper publishers.
- State Newsletter sponsored by the State Technical Services.

- Individual seminars.
- Chamber of Commerce meetings.
- Thorough SBA.
- Trips to individual companies (contact is primarily with libraries rather than with researchers).

## Description of Current and Potential User Groups

Colleges and universities, principally those which are members of the network. Ten academic institutions have already made use of the service.

Industries located in the gulf region - mainly large and medium sized petroleum-oriented industries. Small industries do not have time or money to take advantage of RICE. Forty-seven companies have made requests so far.

## Description of Current System

Personnel and equipment -

- Personnel
  - Five professionals: director, technical director, intern (working on computer applications), two librarians (science information; business information).
  - Two clerks (help professional librarians).
- Equipment
  - 1401 computer.
  - 33SRA teletypewriters.
  - Microfilm readers and printers.
  - Xerox copies.

Input characteristics -

- Citations of all material held by the 18 academic libraries in the network.
- LC MARC tapes.

- Industrial citations (when offered by industries in the gulf region).

Processing of input -

- Procedure will be to put Rice collection on tape first then University of Houston followed by smaller schools.
- For each citation the location of the materials will be indicated.

User input -

- Industry-originated questions: 60% petro-chemical; other ones include electronics, math, space, and economics.
- The more sophisticated companies ask the most difficult questions.
- The larger and more sophisticated the company, the greater the ratio of copying to searching requests.
- Approximately 6,000 pages of copy requested since December 1968.
    - 800 pages requested by academic institutions
    - 4,500 pages requested by industry
- Search requests have increased each month since the system started.
- Types of search questions asked of the RICE System -
    - Patent searches (Cameron Iron).
    - Citation verification (NASA).
    - Literature search on time sharing of computers.
    - Locate authors.
    - Price of a book subscription.
    - What is a particular journal - refractory journal.
    - Information concerning Texas offshore leasing.
    - Who invented the first mercury manometer?
    - Declorination of fluorine.
    - What is NASA doing in the area of geophysics.
    - Information on inert gas.
    - Information on geothermal steamwells.
    - Information on force winds.

Processing of user input by the system -

- If questions are not clear some member of the RICE staff calls the user and determines the requirements more specifically.

Matching of queries with resources -

- At the present time this is done manually by the librarian.
    - . Once the system is automated all searches will be performed by the computer.

Dissemination of output to users -

- Mail xerox copies.
- Teletypewriter to member institutions.

Feedback from users -

- Expressions of satisfaction from industries.
- More requests for copy and searches are received each month.

Charge to users -

- Advanced membership: $5,000
    - . All standard services (access to exchange, regional information locating service, inter-library loan, etc.).
    - . $1,500 worth of photocopying.
    - . $1,500 worth of literature search.

- Special membership: $2,500
    - . All standard services.
    - . $750 photocopying.
    - . $750 literature search.

- Communicating membership: $1,500
    - . All standard services.
    - . $450 photocopying
    - . $450 literature search

- Some companies have small deposit accounts.
- Some companies pay as they use the system.
- Some companies buy memberships to feed the system. (They support it financially but don't make much use of it.)
- There are nine companies with memberships and six companies with deposit accounts.

Performance characteristics -

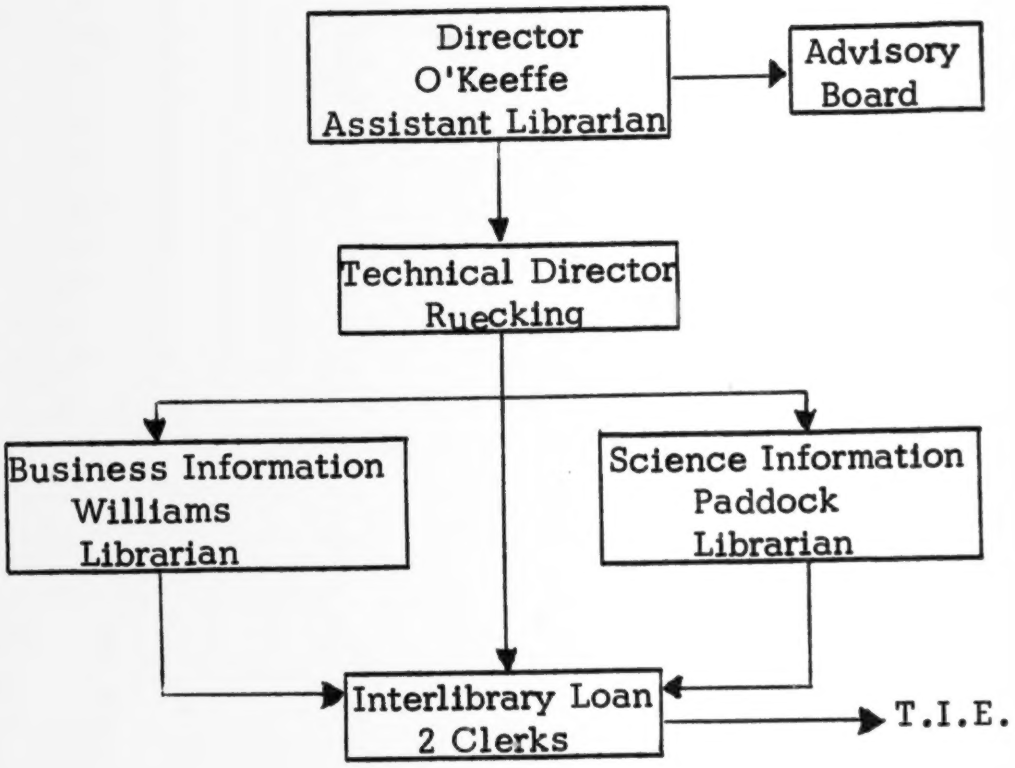
  - Both number of search requests and number of pages of copy have increased each month.

## Plans for the Future

- Put RICE System on self-supporting basis in three years.
- Put the RICE System on-line eventually.
- Eventually will charge less to user organizations which make contributions to the resource base.
- RICE should be made one of the distribution points for MARC tapes.
- Within three years most of the data base will be on tape.
- Eventually integrate Chemical Abstracts SDI Service into RICE System.
- Have 18 members of the network buy in different content areas. This will maximally increase the regional resource base.
- Integrate Technical Information Exchange (TIE) with Regional Information and Communications Exchange (RICE).

## Organization

(next two pages)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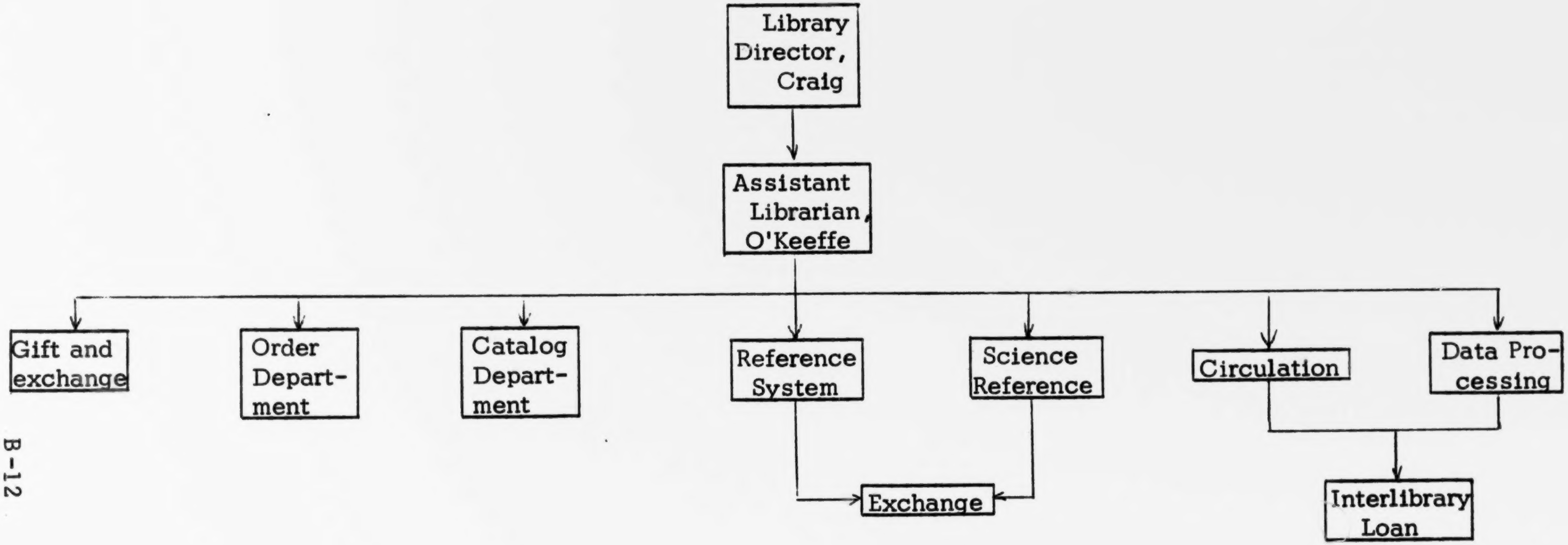
Exchange Organization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Assistant Librarian, O'Keeffe
Gift and exchange
Order Department
Catalog Department
Reference System
Science Reference
Circulation
Data Processing
Exchange
Interlibrary Loan

Library Organization

# SPIRES

## History/Development of System

### Purpose

To determine how to meet the real information needs of a number of diverse groups of scientist and non-scientist users of scientific information. The first group of concern is high energy physicists. The ultimate plan is to have information systems in the home which will provide content on any subject. The computer is seen as a logical extension of the television.

### Development of the System

- The SPIRES project was undertaken by the Institute for Communication Research in 1966.
- The concept is to develop an on-line interactive system.
- So far there is no satisfactory operational general purpose time-sharing system; SPIRES has designed and is currently implementing a special purpose time-sharing system.
- Currently involved in programming bibliographic functions.
- Once bibliographic function is operating satisfactorily, start developing other project related functions for the computer (e.g., simulation, data retrieval, etc.).
- Concern with simplification of user-terminal interaction.
- General concept is that the scientist and the computer will work together to make up the system.
- The current approach is modular development. This

approach facilitates modification. The idea is to have a continuously evolving system; i.e., make the system adaptable to the user.

## Description of Users

One hundred energy physicists working at SLAC--5% of the world's high energy physicists.

## Description of Current System

Personnel and equipment -

- Staff
  - 1/2 time clerk
  - Three system programmers, one application programmer, two part-time student programmers
  - SLAC librarian 1/4 time
  - Ballots senior systems analyst part-time
  - Dr. Parker
  - One secretary

- Equipment
  - IBM 360-67
  - IBM 360-75
  - IBM 3741 typewriter terminals
  - IBM key punch

Input characteristics -

- The current input is composed of the Physics preprints obtained and held in the SLAC library collection. (Acquisition rate: average 50 preprints per week.)
- SLAC obtains preprints from physicists and from Physics laboratories.
- Eventually users will be able to input their personal files.

Processing of input -

- SLAC inputs preprint author, title, author's affiliation, and other citation information including journal name, volume number, and page number for each journal article cited in the footnotes or reference lists. Currently this is being done by the teletypewriter terminal.* Another alternative being evaluated for input is the keypunch.

- Nuclear Science Abstracts bibliographies, citations, and indexing terms.

User input -

- The user will query the system for bibliographic information by means of the terminal.

Processing of user input -

- Computer processes bibliographic search commands.

Matching of queries with surrogate files -

- Computer search programs for matching query terms with terms in index file.

Dissemination of output (search results) to user -

- Search results are transmitted to user at the terminal from the computer. The system is on-line so the user can carry on an active dialogue with the computer files.

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* This input format permits citation indexing searches forward in time using earlier known articles as starting points for the search.

Feedback from users -

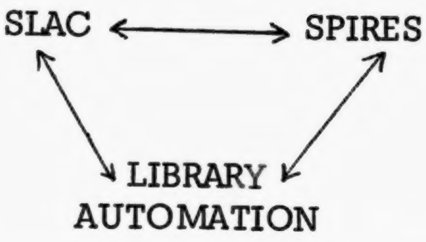
- Behavioral data based on interactions between the user and the computer. (Use data will be kept by the system.)
- User can comment on system performance at the terminal by using "show SPIRES".
- Questionnaires and interviews.

Additional sources of guidance for system development and modification -

- Faculty Advisory Committee responsible for advising and directing.
- Progress being made on BALLOTS: library automation project.
- Characteristics of other systems at Stanford which may impose constraints.
- Progress made on similar systems such as MACTIP at MIT.

## Organization

Three projects -



## Other projects at Stanford With Which SPIRES Should Integrate

Project BALLOTS -

- To process each book, independent of the cost of the book. It costs an average of ten dollars.

- Supported by Office of Education (OE).
- Staff consists of -
  - 4 system analysts
  - 1 programmer
  - 1 librarian
  - some part-time help
- There are about 40 libraries at Stanford. This includes main, branch, and departmental libraries. About 85% of the libraries are served by the main library - that is, responsibility for processing.
- The project has started on the acquisition function - should have this completed by January-February next year.
- They anticipate having the library automated within 3-5 years - probably 5 years.
- Much of the thinking on Project Ballots comes from Dr. Parker - the on-line interactive philosophy, etc.
- They acquire about 100,000 documents a year.

Project information -

- Sponsored by FORD Foundation.
- Concerned with automating the administrative and accounting functions of the university.
- There is some pressure to incorporate Project Information into Projects SPIRES and BALLOTS.

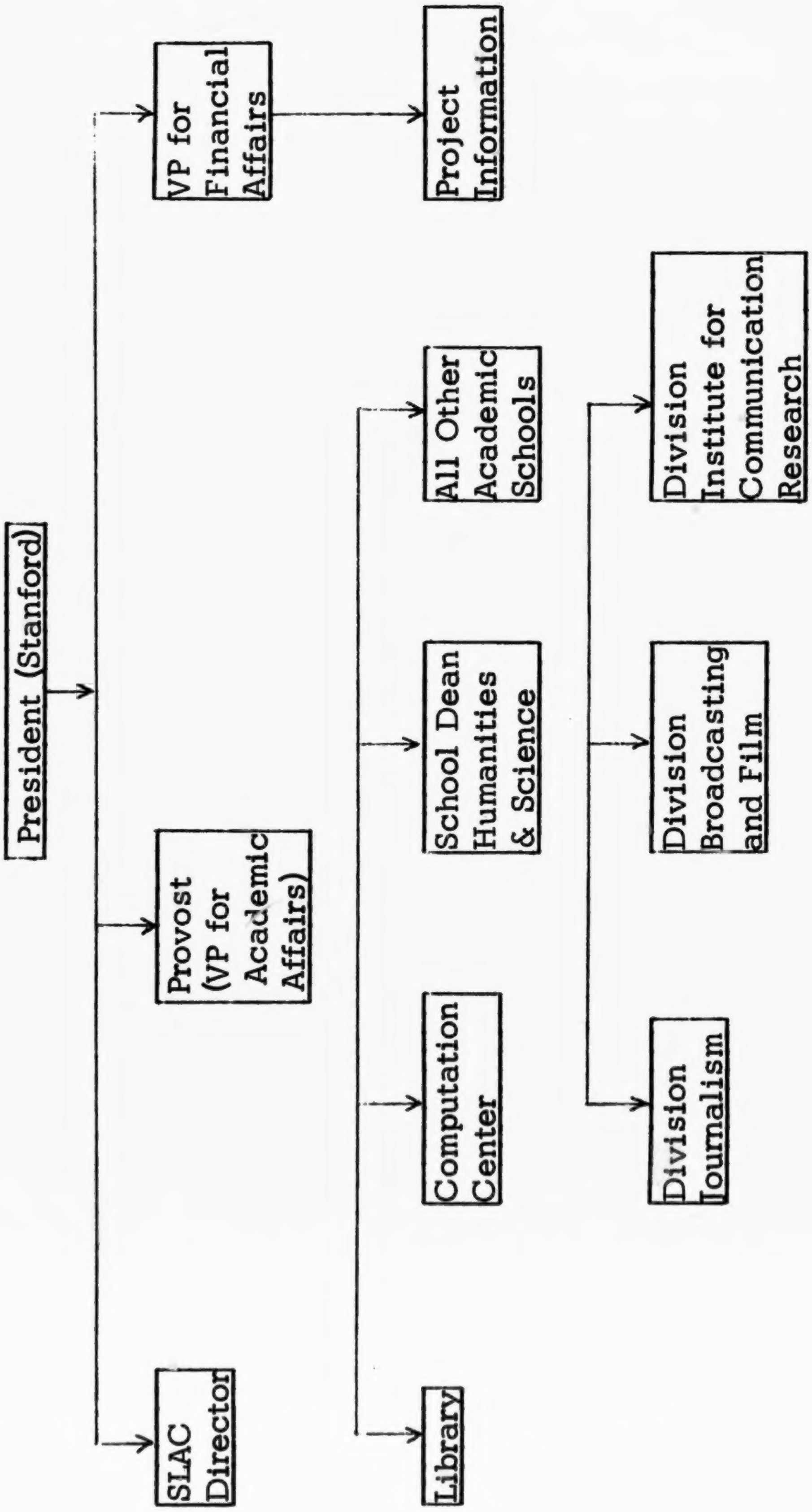
Project SLAC -

- SLAC already had manually processed a pre-print collection.
- Formal arrangements with high energy physicists and institutions doing work in this field had already been made.
- The interviews (depth interviews of 1 hour duration) uncovered the interest in having pre-preprints or what is scheduled to be done by whom in the way of an experiment.

- Another feature uncovered in the interviews is the trend towards CRT displays rather than typewriter outputs.
- Also interviewees wanted personal files and 24 hour availability.

Organization

(next three pages)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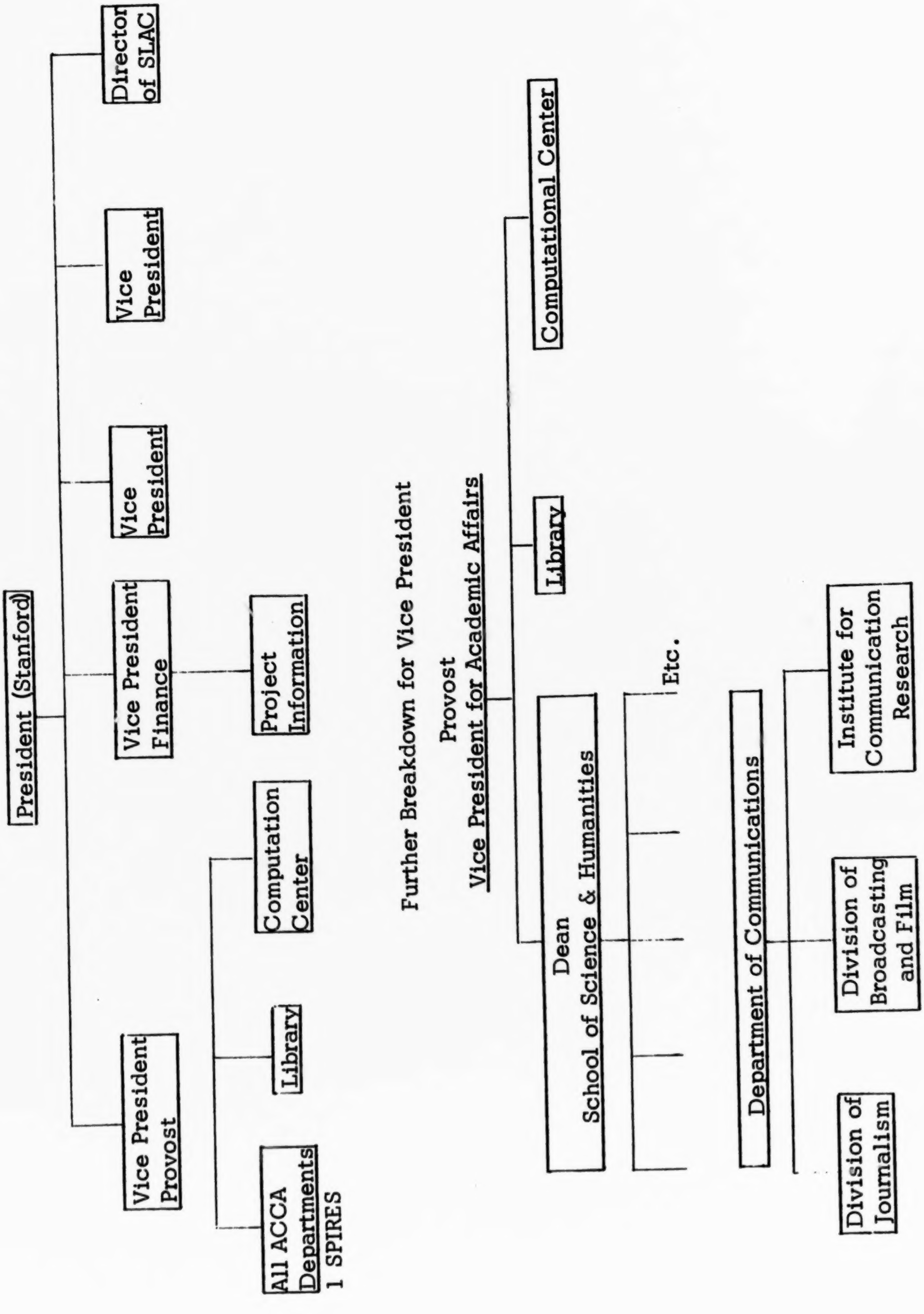
SLAC Director
Provost (VP for Academic Affairs)
VP for Financial Affairs
Project Information
Library
Computation Center
School Dean Humanities & Science
All Other Academic Schools
Division Journalism
Division Broadcasting and Film
Division Institute for Communication Research


President (Stanford)
Vice President Provost
Vice President Finance
Vice President
Vice President
Director of SLAC
All ACCA Departments
1 SPIRES
Library
Computation Center
Project Information
Further Breakdown for Vice President
Provost
Vice President for Academic Affairs
Dean School of Science & Humanities
Library
Computational Center
Etc.
Department of Communications
Division of Journalism
Division of Broadcasting and Film
Institute for Communication Research

Note: Recently projects BALLOTS and SPIRES have been merged organizationally. They are jointly directed by an executive committee chaired by the Associate Provost for computing. Other committee members include:

- Director of the Computation Center
- Director of Libraries
- Principal Investigator of BALLOTS
- Principal Investigator of SPIRES

# Brain Information Service (BIS)

## Historical Information

### Purpose

To supply information relevant to brain research on a national level.

### System Development and Initial Operation

- BIS was established in 1964 on an entirely manual basis.
- In 1965 conversion to a computerized system was initiated.
  - Early in 1965 system specifications were developed and documented.
- Problems associated with computerizing system.
  - Lack of qualified personnel - no systems analysts, no programmers.
  - Developing a Thesaurus for automatically indexing titles. Concept: include every word in title as indexable - this created a problem: list of words - infinite.
  - Type of computer for which programs were to be written was changed three times: 7040; 7094; 360-75. With each change, new programs had to be written for the bibliographic retrieval system. The program for the 360-75 should be operational by August 1968.

## User Groups

Approximately 300 users. Half of the users are local (Brain Research Institute) the rest are spread around the country (many of these were connected with Brain Research Institute (BRI) at one time or another).

## Current System Characteristics

Equipment and personnel -

- 360-75 computer
- 3 1/2 librarians: area specialists
- 10 clerical personnel

Input characteristics (document) -

- MEDLARS tapes
- Current journals (punched on cards)
- Books and journals back to 1960 (punched on cards)
- All library materials available at UCLA
- 30 or 40 journals subscribed to by BIS

User input -

- Specific questions
- Requests for bibliographies
- Current awareness areas of interest

System processing of user input -

- Librarians work directly with scientists to determine their requirements.
- Requests for information are currently processed manually (i.e., searches are conducted by librarians and bibliographies are compiled).
- For current awareness, incoming journals are scanned by librarian for relevant articles (BIS and UCLA library). For 15 journals the tables of contents are xeroxed and sent around. Users can order articles by checking those that are desired.

Additional services offered -

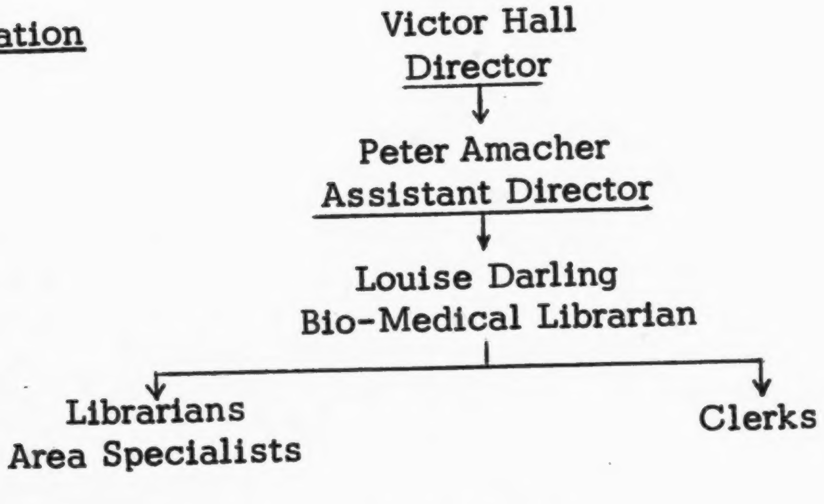
- Workshops and conferences set up on various topics: participants give papers - these are published - editor is usually a member of the Brain Research Institute staff.

- Bibliographies published on specific subject areas.
- Updated reviews in selected areas of neurophysiology. This includes all relevant literature (updating is done every 4-6 weeks).
    - These reviews are written and updated by members of the Brain Research Institute. They may receive payment through honorariums, etc.
- Written on three levels of detail; each of which is complete. (a) graduate student with general interest - level 1; (b) graduate student with specific interest - levels 1 and 2; (c) research scientist - levels 1, 2, and 3.
    - These reviews will eventually be indexed and made available through the computer.
- Provides index and abstracts for pre-published articles - these are published in Section B of "Communications in Behavioral Biology" - 3-6 weeks time lag. Section A of this journal includes articles received within the last 6-7 weeks.

## Feedback From Users

- Nothing systematic. Based on conversations between users and librarians. Most users have indicated a high degree of satisfaction (particularly pleased with the dissemination of xeroxed tables of contents).
- Two user studies.
    - What journals are used.
    - What ranks read what (highest readers - associate professor level; full professor reads more than instructors and assistant professors).

## Organization



## Funding

All money comes from NIMDB.

## BIS

BIS is part of a network which includes Harvard, Columbia, and Johns Hopkins. BIS is concerned with basic content areas; each of the other three concentrate on a clinical field. As of now there is little coordination. However, plans for the future include increased cooperative efforts.

## Knowledge Availability System (KAS) Center

### History and Development of System

#### Purpose

The Knowledge Availability System Center was established in 1963 by the University of Pittsburgh to develop a program of research, operations, and teaching. The first major operational program undertaken by the KAS Center was fostered by NASA in 1964 as a Regional Dissemination Center (RDC) for NASA publications. One original goal of the operational program was to make the RDC self-supporting by 1969. The Technology Utilization Division of NASA is responsible for the dissemination of materials to the regional centers.

#### Development and Initial Operation

Initially the system required highly imaginative, creative, and motivated personnel to participate in the development and shaping of the system. Once this work was completed, personnel were needed who were useful in performing more routine tasks.

When the system first became operational it had eleven companies in its user group. At one time in the last four years this center was serving as many as 75 companies.

### Marketing Procedures

Steps involved in identifying potential user companies and making them aware of the services offered by the knowledge availability systems center -

- Select potential user companies from industries listed in Dun and Bradstreet.

- Make an initial determination concerning the match between the system's (center's) current data base and the content needs of these industries.
- Send a brochure (information package) to the selected industries.
- If the response of the contacted industries is favorable then a follow-up visit is made.
- If the visit is successful and the company(s) wishes to subscribe to the services of the center, make up a purchase order and have it signed by the company.
- The signing of the purchase order is followed by a visit to the company by a consultant (one of the engineering faculty or the Associate Dean of Engineering) who works with employees to determine their basic information needs.

## Description of Current and Potential User Groups

- Sixty-two large and medium-sized industries located in Pennsylvania, Ohio, New York, New Jersey, and West Virginia.
- Colleges and universities in Pennsylvania through the State Technical Services Act.
- Materials Engineering Magazine (a trade magazine) - used to advertise abstracts to subscribers.
- University of Pittsburgh faculty and graduate students (get money from the university budget).

## Description of Current System

Personnel and equipment -

- Forty-four staff members
    - Thirteen professionals - content experts, systems analysts (seven are full-time).
    - Eleven consultants - these are all members of the engineering faculty.
    - Twenty clerical (sixteen are full-time).
- Equipment
    - 7090 (IBM)
    - Xerox
    - ITEK microfiche printer

Input characteristics -

- NASA tapes: STAR and AIAA - include index entries and accession numbers(indexing for STAR items is done by Documentation Incorporated).
- Unit records for all titles in STAR and AIAA.
- Microfiche of documents listed in STAR (all files go back to 1962).
- NASA data base - 300,000 documents - 60,000 are added each year.

Processing of input -

- Abstract cards are kept in order by accession number back to 1962.
- Microfiche for STAR documents (N-documents) is filed by accession number. No hard copies are stored.
- Four magnetic tapes including index entries and accession numbers are used for computer input. These tapes are stripped versions of the 18 tapes supplied by NASA. There is a substantial amount of non-index information on the NASA tapes which is not utilized by the Knowledge Availability Systems Center.
- Materials are located at Space Coordination Research Center and Hotel Webster Hall.

User input*-

- The users supply the center with questions in specified content areas. These questions are developed by the user and a consultant from the system (one of the eleven members of the engineering faculty or one of the five subject specialists).
- A consultant is assigned to each question and gets in touch with the user once every three months.
- At the present time the system is processing approximately 700 questions a month.

Processing of user input by the center -

- Subject specialists develop search strategies from questions using NASA Thesaurus.

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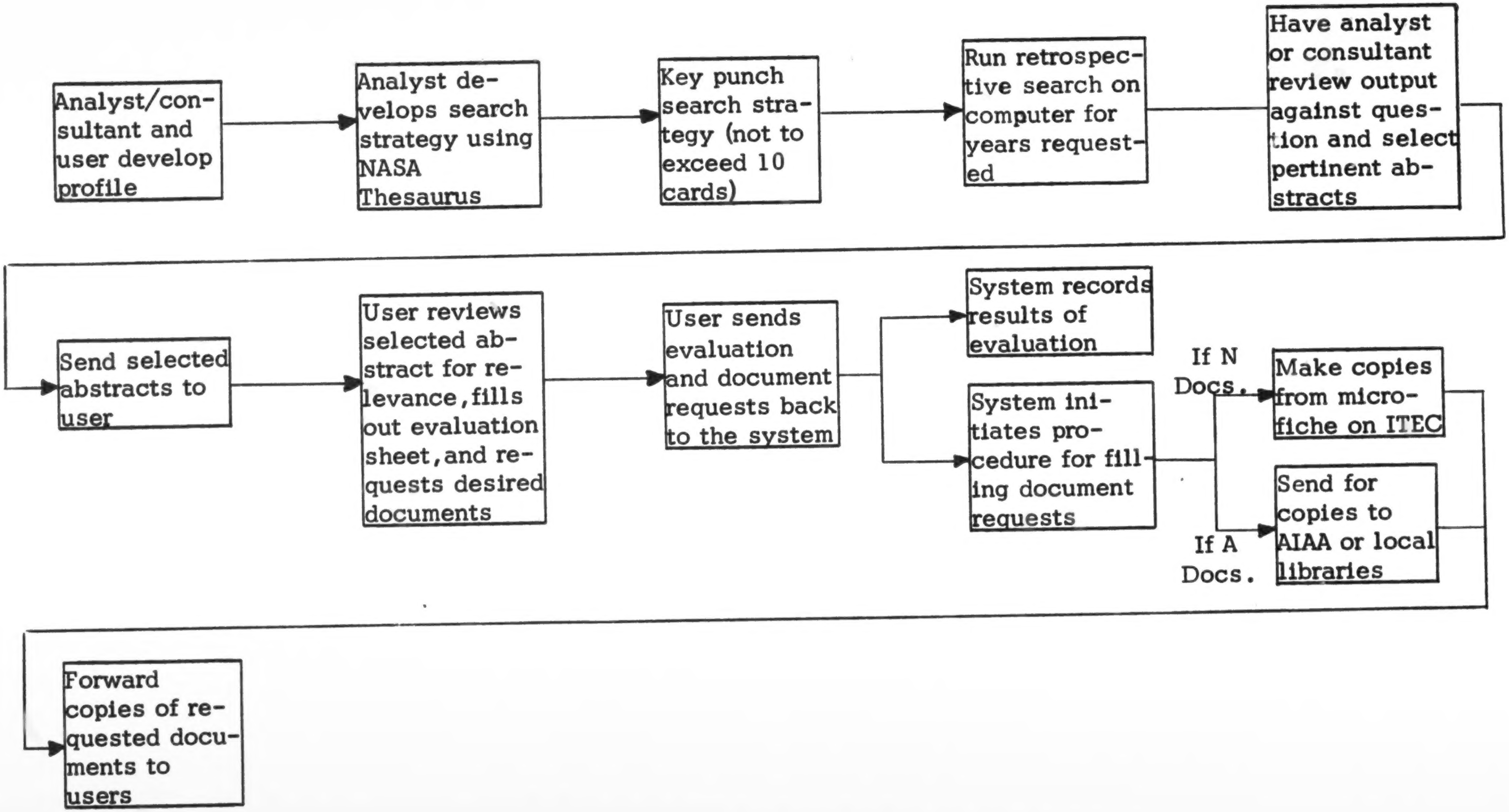
* See Figure 1 for user/system interaction.

FIGURE 1

SYSTEM/USER INTERACTION


Analyst/consultant and user develop profile
Analyst develops search strategy using NASA Thesaurus
Key punch search strategy (not to exceed 10 cards)
Run retrospective search on computer for years requested
Have analyst or consultant review output against question and select pertinent abstracts
Send selected abstracts to user
User reviews selected abstract for relevance, fills out evaluation sheet, and requests desired documents
User sends evaluation and document requests back to the system
System records results of evaluation
System initiates procedure for filling document requests
If N Docs.
If A Docs.
Make copies from microfiche on ITEC
Send for copies to AIAA or local libraries
Forward copies of requested documents to users

Matching of user-questions with NASA tapes -

- Questions are matched with magnetic tape entries using Boolean Search Strategy (selected accession numbers are matched with abstract cards by hand).
- If questions are not receiving any citations from NASA a hand search of USGRDR and Nuclear Science Abstracts is performed.
- For most questions an initial retrospective search is performed. For each of the following twelve months current awareness searches are performed.
- Reviewers examine abstract cards selected for each question and select relevant abstracts. Approximately 30% of abstract cards are selected by the consultants.

Dissemination of selected output to users -

- Abstracts are sent one month for the retrospective search and each of the following twelve months for the current awareness service.
- If documents (hard copy or microfiche) are requested, these are provided by the system. For N-documents - hard copies are made from microfiche file; for most A-documents copies are obtained from local libraries/ information centers.

Feedback from users -

- For each set of abstracts sent users are asked to evaluate them for relevance. Currently, approximately 80% of the abstracts sent are rated as relevant.
- The same forms are used for ordering documents from the center (4,114 documents were requested and supplied during the first quarter of 1968).

Charge to users -

- Type I Service: Subscribers will receive a computer print-out which lists the accession numbers of cited documents.
    - . Current awareness - $50.00 per profile.
    - . Retrospective - $55.00 per profile.
    - . Current awareness and retrospective - $75.00 per profile.

- Type II Service: Subscribers will receive abstracts of all documents cited by the computer search.
    - . Current awareness - $85.00 per profile.
    - . Retrospective - $90.00 per profile.
    - . Current awareness and retrospective - $135.00 per profile.
- Type III Service: Subscriber will receive Engineering Review plus relevant abstracts.
    - . Current awareness - $180.00 per profile.
    - . Retrospective - $185.00 per profile.
    - . Current awareness and retrospective - $275.00 per profile.
- Type IV Service: Subscriber will receive abstracts of cited documents which reflect interests of users in general in a subject area. No specific changes can be made to satisfy the individual user.
    - . Standard interest profile - $100.00 per profile.
- Profile substitution may be made on a current awareness search service for a file of $10.00 per profile.
- Document charges -
    - . Hard copy - $.05 per page of original document.
    - . Hard copy (custom format and size) - $.10 per page of original document.
    - . Microfiche - $.50 per document.

Performance characteristics -

- The center uses the 7090 computer between 2-3 hours a month.
- A minimum of six questions per computer run.
- There were eleven aborts during the first three months of 1968.
    - . Ten were due to card punching errors.
    - . One was due to tape damage.
- The ITEK reproduces 1 1/2 pages per minute. (microfiche to hard copy)
- Approximately two weeks turn around for initial retrospective search.

Costs -

- Approximately 1/3 million dollars a year is required to operate the center.
- Costs have been broken down into the following categories:
    - . Professional
    - . Clerical
    - . Overhead
    - . Fringe benefits
    - . Travel
    - . Computer time
    - . Materials
    - . G and A
- Industrial users provide approximately 1/3 of funds.

## Plans for the Future

Users in addition to current groups -

- Colleges and universities in Pennsylvania through State Technical Services Act (provide abstracts in 31 areas - 31 standard questions). (See Table 1 for standard interest profiles.)
- Professors and graduate students at the university through university budget.

Expansion of data base beyond NASA -

- Chemical Abstracts tapes processed by Chemical Information Center.
- Nuclear Science Abstracts tapes.
- Social Science Data Archives tapes.
- DDC tapes.
- Engineering Index tapes.

Revision of Free Schedule (Table 1) -

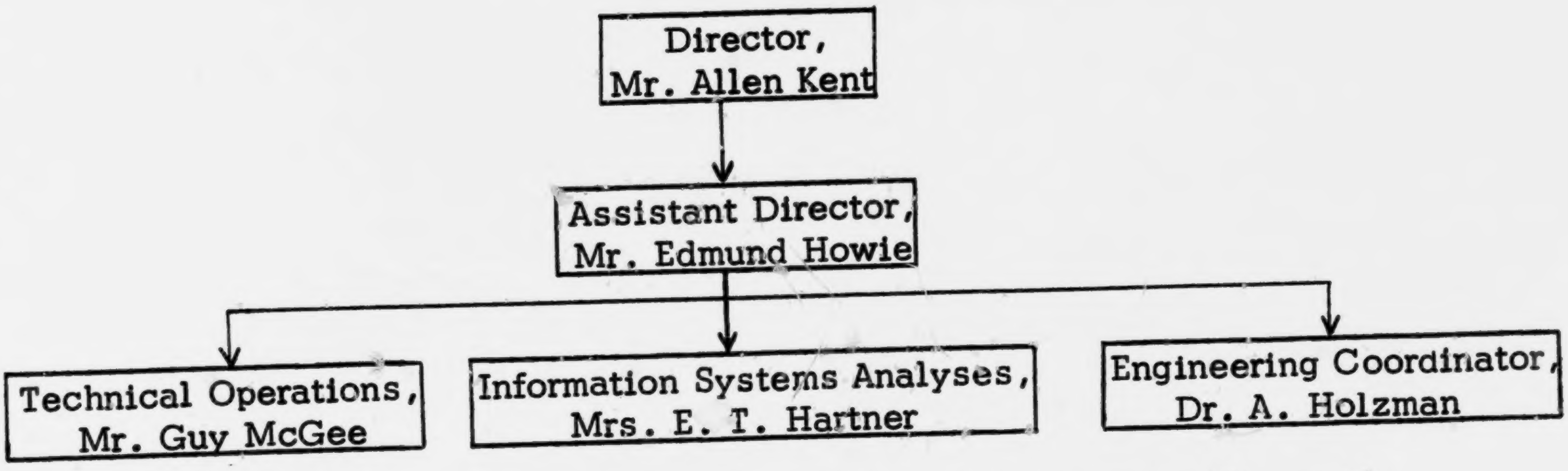
- In addition to charge will be made for documents and microfiche requests.

## Table 1

## Available Standard Interest Profiles

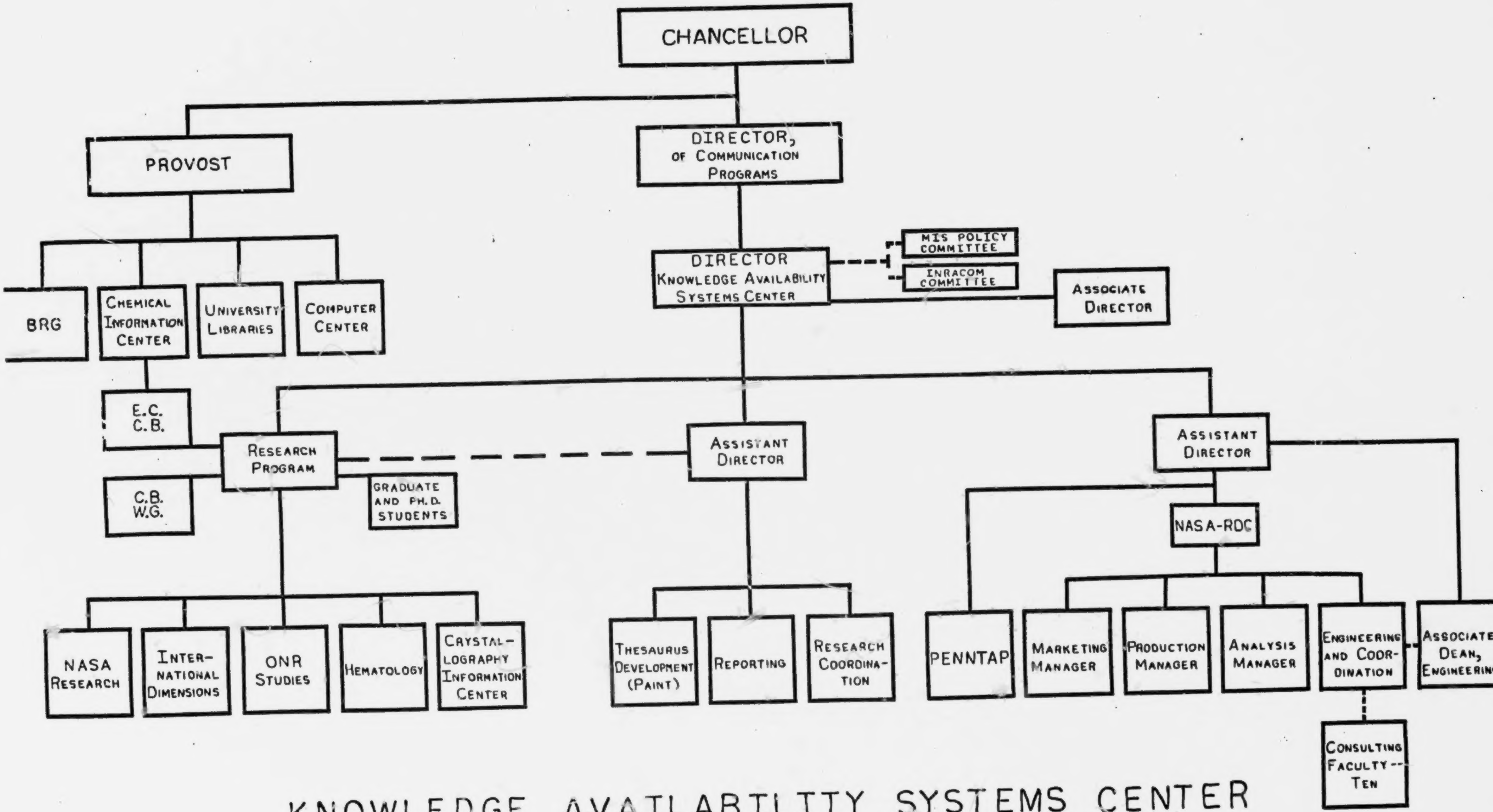
Ceramics, Cermets, Glass
Elastromers
Plastics
Nuclear Materials
Fiberglass and Fiber-reinforced Plastics
Composite Materials
Powdered Metals and Powder Metallurgy
Lubrication and Lubricants
Foods
Forming Techniques
Machining and Cutting
Cleaning and Sterilization Techniques
Joining and Welding
Adhesives and Adhesion
Surface Protection and Hardening
Non-destructive Testing and Quality Control
Reliability/Life Testing
Experiment Design (Statistical)
Instrumentation and Devices for Testing and Measuring
Analyses for Chemical Composition
Crystal Growth
Equilibrium, Constitution, and Phase Diagrams
Bearings
Electrical Insulation
Power Sources
Bioinstrumentation
Information Science
Management Techniques
Steels
Corrosion and Stress Corrosion of Metals and Alloys
Fluid Flow, Fluid Mechanics, Heat Transfer

## Organization of Knowledge Availability Systems Center


Director,
Mr. Allen Kent
Assistant Director,
Mr. Edmund Howie
Technical Operations,
Mr. Guy McGee
Information Systems Analyses,
Mrs. E. T. Hartner
Engineering Coordinator,
Dr. A. Holzman

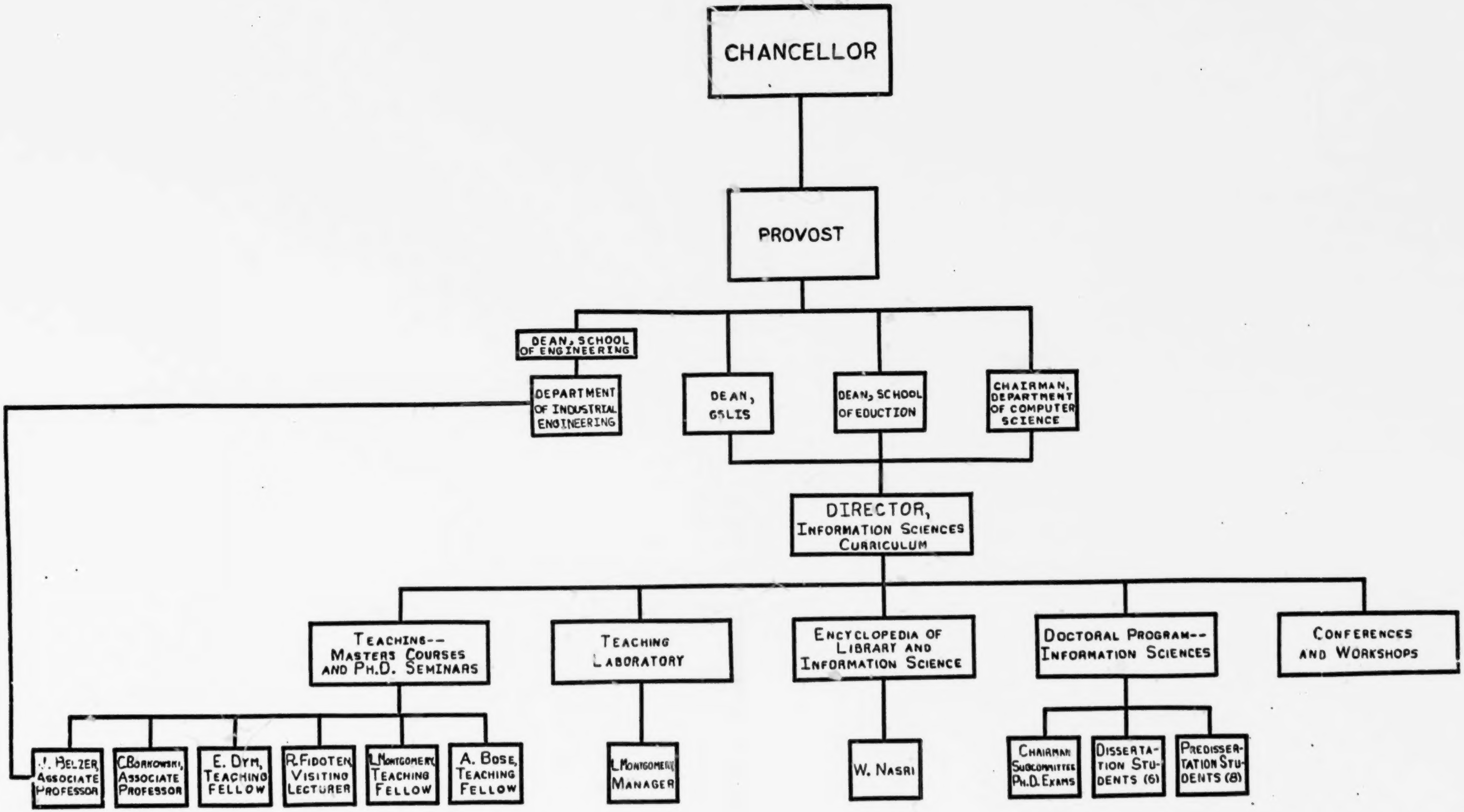
- Administrative organization within the university (Figure 2).
- Academic organization within the university (Figure 3).

FIGURE 2


CHANCELLOR
PROVOST
DIRECTOR, of COMMUNICATION PROGRAMS
DIRECTOR KNOWLEDGE AVAILABILITY SYSTEMS CENTER
MIS POLICY COMMITTEE
INRACOM COMMITTEE
ASSOCIATE DIRECTOR
BRG
CHEMICAL INFORMATION CENTER
UNIVERSITY LIBRARIES
COMPUTER CENTER
E.C. C.B.
C.B. W.G.
RESEARCH PROGRAM
GRADUATE AND PH.D. STUDENTS
ASSISTANT DIRECTOR
ASSISTANT DIRECTOR
NASA-RDC
NASA RESEARCH
INTER-NATIONAL DIMENSIONS
ONR STUDIES
HEMATOLOGY
CRYSTAL-LOGRAPHY INFORMATION CENTER
THESAURUS DEVELOPMENT (PAINT)
REPORTING
RESEARCH COORDINA-TION
PENNTAP
MARKETING MANAGER
PRODUCTION MANAGER
ANALYSIS MANAGER
ENGINEERING AND COOR-DINATION
ASSOCIATE DEAN, ENGINEERING
CONSULTING FACULTY--TEN

KNOWLEDGE AVAILABILITY SYSTEMS CENTER
ORGANIZATION — ADMINISTRATIVE

FIGURE 3


CHANCELLOR
PROVOST
DEAN, SCHOOL OF ENGINEERING
DEPARTMENT OF INDUSTRIAL ENGINEERING
DEAN, GSLIS
DEAN, SCHOOL OF EDUCTION
CHAIRMAN, DEPARTMENT OF COMPUTER SCIENCE
DIRECTOR, INFORMATION SCIENCES CURRICULUM
TEACHING-- MASTERS COURSES AND PH.D. SEMINARS
TEACHING LABORATORY
ENCYCLOPEDIA OF LIBRARY AND INFORMATION SCIENCE
DOCTORAL PROGRAM-- INFORMATION SCIENCES
CONFERENCES AND WORKSHOPS
J. BELZER, ASSOCIATE PROFESSOR
C. BORKOWSKI, ASSOCIATE PROFESSOR
E. DYM, TEACHING FELLOW
R. FIDOTEN VISITING LECTURER
L. MONTGOMERY TEACHING FELLOW
A. BOSE, TEACHING FELLOW
L. MONTGOMERY MANAGER
W. NASRI
CHAIRMAN SUBCOMMITTEE PH.D. EXAMS
DISSERTATION STUDENTS (6)
PREDISSERTATION STUDENTS (8)

KNOWLEDGE AVAILABILITY SYSTEMS CENTER
ORGANIZATION — ACADEMIC

## PENNTAP Library Information System

### History/Development of System

#### Purpose

PENNTAP was established in 1966 to implement some of the directives set forth in the State Technical Services Act of 1965. This act is concerned with supplying technical services to industrial organizations.

#### Development and Initial Operation

- The development of the PENNTAP Library Information System was carried out by Mr. Anthony Venett. Based on his background and prior experience with industry, Mr. Venett felt that the most critical function that he could perform would be to direct industry to the answers to their specific question.
- Initially three pilot areas in Pennsylvania were selected -
    - York
    - Reading
    - Erie
- Twenty companies were initially contacted.
- Industries located in these areas were to contact their local commonwealth campus and give them their question(s) (there are 20 commonwealth campuses in Pennsylvania).

### Marketing

Some individual visits have been made to companies. However, this is not possible to do on an extensive basis with the currently limited staff.

- In the summer of 1967 a faculty member at Penn State was employed to visit industries in the Erie area and talk to them about PENNTAP (approximately 25% return on this).

Much of the marketing is done at local meetings (e.g., speeches given to Chamber of Commerce, etc.).

Marketing tools -

- Nine-minute film on how PENNTAP Library Information System helped a Pennsylvania Industry to change its procedures and save money.
- A brochure on what PENNTAP can offer state industries.

If company is satisfied with PENNTAPS output it will continue to use the service.

## Description of Current and Potential User Groups

- Currently there are 95 companies that are using or have used this system. Most of these are medium sized companies and small research oriented companies. Small manufacturing companies are too busy with administrative and production related tasks. These small companies have no time for research. The large companies have their own library resources.
- Most of these 95 companies are located in the three pilot areas.
- No businesses are included.

## Description of Current System

Personnel and equipment -

- The staff includes: 1 professional, a secretary, and two clerks. In addition, librarians on the commonwealth campuses are used, however, they are not paid by PENNTAP funds.
- Xerox machine.
- Facsimile transmitter.
- WATS line.

Input characteristics -

- Scope: information on technology and applied sciences. No patents searching is included.

- PENNTAP Library has no formal collection of materials. Mr. Venett has in his office a few indexing and abstracting journals (e.g., American Society for Metals, Metals Abstracts, etc.), also some abstracts from Knowledge Availability System Center (31 areas).
- Principal information resources drawn on by PENNTAP include:
  - . Carnegie Library: Pittsburgh
  - . University of Pittsburgh Library
  - . Philadelphia Free Public Library
  - . The Penn State University Libraries
  - . Hershey Medical Center
  - . Federal Libraries (LC, NLM, and Agriculture)

User input -

- Questions are submitted to local commonwealth campus or to Mr. Venett directly, by telephone, or in writing.
- Content of questions - industrial processes or products.
- Questions must be specific; general questions are not responded to (e.g., state-of-the-art, etc.).
- 320 questions have been received over the past 17 months. Approximately 20 questions are asked each month.

Processing of user input -

- About 5% of the questions are handled by the commonwealth campuses.
- The remaining 95% of the questions are forwarded to Mr. Venett.
- Generally, Mr. Venett will call the industry to clarify the question after he receives it (use WATS line).

Matching of questions with available information sources -

- For each question searches are conducted.
- First step is to consult relevant abstracts and indexes.
- Searches go back as far as necessary (e.g., went back to 1890's for information on how to build windmills).
- If no information can be found Penn State faculty members may be consulted for possible leads.

- Once relevant materials are identified, these are obtained and scanned.
- Relevant sections are xeroxed for the user (usually does not exceed 20 pages).
- If government documents are identified the reference is usually recommended, however, PENNTAP does not buy these documents for its users.
- Exhaustive background searches are not conducted.
- If necessary, PENNTAP will provide a list of consultants.

Dissemination of selected output to users -

- Xerox copies are mailed to users.
- For fast service, xerox copies are transmitted over facsimile equipment (when only a few pages are needed) to appropriate commonwealth campus and commonwealth campus contacts the users.

Feedback from users -

- A questionnaire concerning relevance of received materials was sent out to participating companies.
- Eighty-five questionnaires were sent out and 69 returned. No results are currently available.
- Some critical incidents where industries have modified their processing as a result of information supplied by PENNTAP.

Charge to users -

- All information is provided free to industries.

Performance characteristics -

- Of the 320 questions asked during the past 17 months, 25 could not be answered and four did not deal with technology.
- Average search time to answer a question is five hours.
- Average turn around time on a question is two weeks.
- Not enough money or staff to provide current awareness or state-of-the-art.

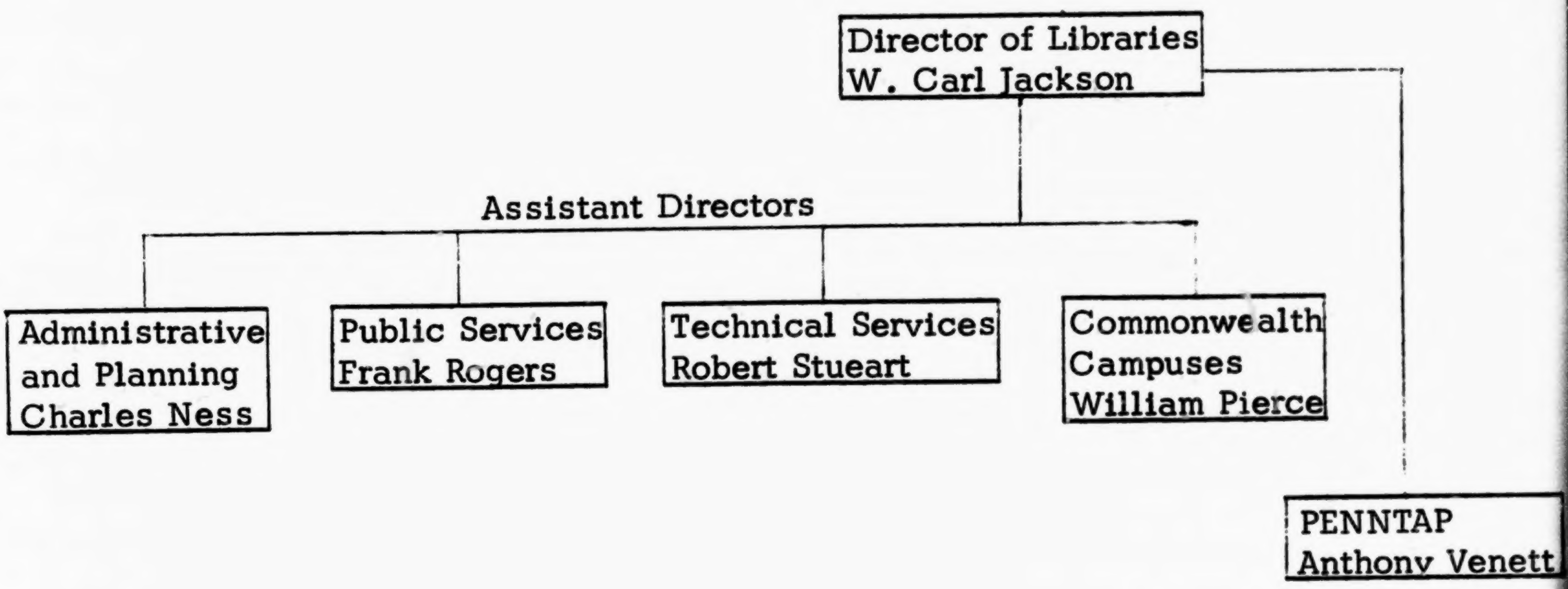
Costs -

- Budget of approximately $60,000 a year.
    - Supplies and publications.
    - Wide area telephone (WATS).
    - Postage.
    - Instructional supplies.
    - Travel.
    - Equipment (xerox and facsimile . . . )
    - Salaries
    - Wages
    - Overhead
- The university takes 20% of $60,000 for their overhead.
- Each year submit two budgets: one for continuing at same level of effort; one for expanded level of effort.

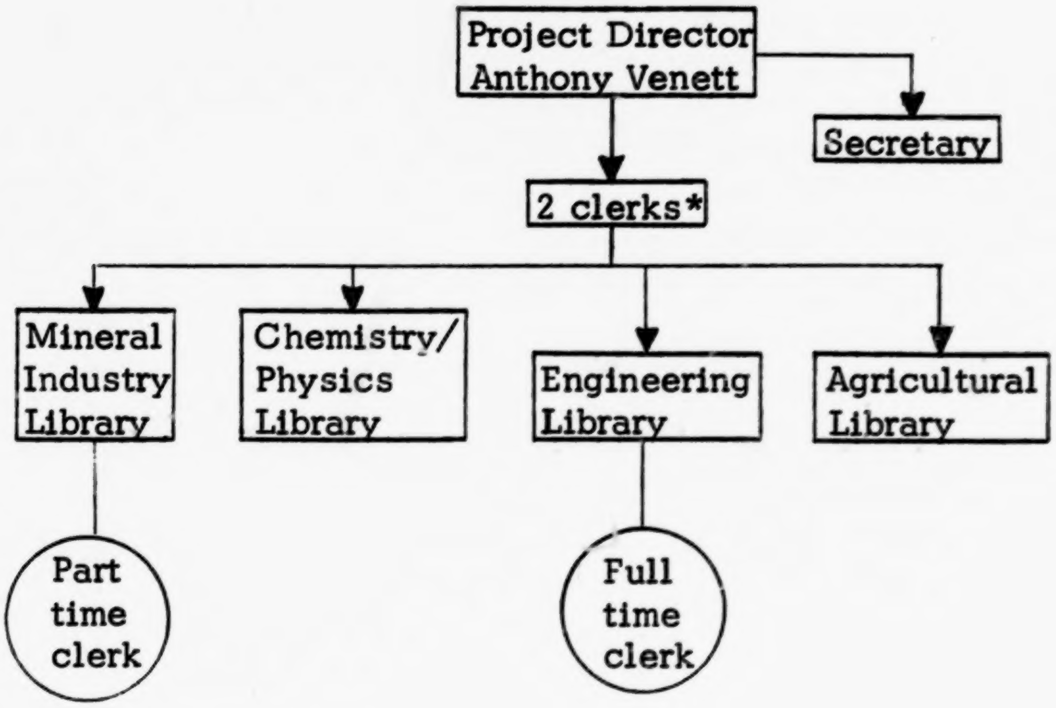
## Plans for the Future

- Hire an assistant for next year.
- Start moving into other areas of the state: Allentown - Bethlehem.
- Eventual state wide operation.

## Organization


Director of Libraries
W. Carl Jackson
Assistant Directors
Administrative and Planning
Charles Ness
Public Services
Frank Rogers
Technical Services
Robert Stueart
Commonwealth Campuses
William Pierce
PENNTAP
Anthony Venett

## PENNTAP


Project Director
Anthony Venett
Secretary
2 clerks*
Mineral Industry Library
Chemistry/ Physics Library
Engineering Library
Agricultural Library
Part time clerk
Full time clerk

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[*] PENNTAP will get an assistant technical librarian in the summer, 1968 with a MS in Library Science. Assistant has had experience in medical/ biological areas.

## Regional Information and Communication Exchange
## (RICE)

| Input | Internal Functions | Output |
|---|---|---|
| Information Input:<br>. Citations of all materials held by the 18 academic libraries in the network<br>. Library of Congress MARC tapes<br>. Industrial citations when offered by industries in the region<br>User Input:<br>. Requests for copying<br>. Search requests<br>. Industry originated questions:60% petrochemical; other areas include electronics, math, space, economics<br>. Requests received by mail, over a teletypewriter, or by phone | Processing of Information Input:<br>. In developing the central computer-stored catalog the procedure will be to put the Rice collection on tape first and then the University of Houston followed by smaller schools<br>. For each citation the location of materials will be indicated<br>Processing of User Input:<br>. All questions are reviewed by a special librarian. If a question is not clear, the librarian contacts the user to determine the requirements more specifically<br>Matching of Queries With Information Resources:<br>. Searches are currently conducted by special librarians and their assistants<br>. Once the system is automated all bibliographic searches will be conducted by the computer | Dissemination of Output to Users:<br>. Mail xerox copies of selected materials<br>. Transmit by means of teletypewriter to member institutions |

# SPIRES

| Input | Internal Functions | Output |
|---|---|---|
| Information Input:<br>. Citations and associated information on preprints contained in the SLAC collection (these are input by means of an IBM teletypewriter terminal)<br>User Input:<br>. Queries to the system for bibliographic information using teletypewriter terminal<br>. Eventually will be able to input personal files | Processing of Information (Citation) Input:<br>. Citations are input to the computer by teletypewriter terminal. All citations are available on-line<br>Processing of User Input:<br>. Translation of user commands to system language<br>Matching of User Input With Information Input:<br>. Bibliographic search programs are being developed | Dissemination of Selected Material to User:<br>. Search results are transmitted to the user at the terminal<br>. The user can carry on an active dialogue with the computer files |

## Brain Information Service
## (BIS)

| Input | Internal Functions | Output |
|---|---|---|
| Information Input:<br>. MEDLARS tapes<br>. Current journals<br>. Books and journals back to 1960<br>. Updated reviews in specific areas<br>User Input:<br>. Specific questions<br>. Requests for retrospective searches<br>. Current awareness profiles or key words | Processing of Information Input:<br>. Punching citation information for books and journals on cards<br>Processing of User Input:<br>. Librarians work directly with scientists to determine their information requirements (all requests are currently processed manually)<br>Matching of User Input With Information Input:<br>. Retrospective searches are conducted by special librarians and bibliographies are compiled. Work is currently being done on developing a bibliographic search program for the computer<br>. For current awareness, incoming journals are scanned by librarians for relevant information. This function will be taken over by the computer<br>Additional Functions:<br>. The tables of contents of 15 journals are xeroxed and disseminated to members of the Brain Research Institute<br>. Provides index and abstracts for pre-published articles (from BRI) to "Communications in Behavioral Biology" | Dissemination of Selected Materials to Users:<br>. Materials are carried to local users<br>. Sent through the mail to off campus users |

## Knowledge Availability Systems Center (NASA RDC)

| Input | Internal Functions | Output |
|---|---|---|
| Information Input:<br>. NASA tapes (STAR and AIAA) from 1962<br>. Unit records for all titles in STAR and AIAA<br>. Microfiche of documents listed in STAR<br>. USGRDR and TAB<br>User Input:<br>. Questions in specified content area developed by user and consultant from system | Processing of Information Input:<br>. Abstract cards and microfiche for STAR documents are filed by accession number<br>. Original NASA tapes are stripped. Resulting tapes contain only index entries and accession numbers. These are used as computer input<br>Processing of User Input:<br>. Subject specialists develop search strategies from questions using NASA Thesaurus<br>. Each user is contacted by a system consultant every 3 months<br>Matching of User Input With Information Input:<br>. Questions are matched with magnetic tape entries using Boolean search strategy<br>. Reviewers examine cards selected for each question and select relevant abstracts (approximately 30% of abstract cards are selected)<br>. For each question an initial retrospective search is performed. For each of the following 12 months current awareness searches are performed.<br>Processing of Hard Copy Requests:<br>. For N-documents (STAR listings) hard copies are made from the microfiche file<br>. For A-documents (AIAA) copies are obtained from NASA or local libraries/information centers | Dissemination of Selected Output to Users:<br>. Abstracts are sent one month for retrospective search and for each of the following 12 months for current awareness service<br>. If hard copies or microfiche are requested, these are provided by the system |

## PENNTAP

| Input | Internal Functions | Output |
|---|---|---|
| Information Input:<br>. PENNTAP has no formal collection of materials<br>. Principal information sources include:<br>- Penn State library<br>- Carnegie library<br>- University of Pittsburgh library<br>- Philadelphia Free Public library<br>- Local Medical Center<br>- Federal libraries (LC, NLM, Agriculture)<br>User Input:<br>. Questions submitted by mail or telephone to Penn State or one of the Commonwealth campuses<br>. Questions generally concern industries products or processes<br>. No general state-of-the-art type questions or patent searches are accepted | Processing of User Input:<br>. Most of the questions are handled by the PENNTAP personnel at Penn State<br>. Generally the industry is called to clarify the question once it has been reviewed by PENNTAP personnel<br>Matching of Questions With Available Information Sources:<br>. Manual searches are conducted for each question. No exhaustive searches are undertaken<br>. Searches go back as far as necessary to determine answers. If no information can be found Penn State faculty members may be consulted for possible leads<br>. Once relevant materials are identified they are scanned and appropriate sections are xeroxed for the user | Dissemination of Selected Materials:<br>. Xerox copies of extracted information is transmitted to appropriate commonwealth campus by means of facsimile transmission equipment<br>. Commonwealth campus sends results to local industry(s) |